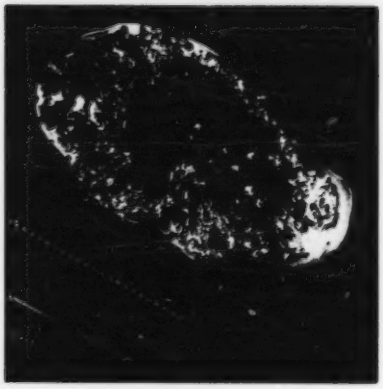
Alberta Hail Project
Field Program 82

Atmospheric Sciences



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ALBERTA HAIL PROJECT FIELD PROGRAM
1982

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Cover Photo

A thin section of a hailstone viewed through polarized light. The crystal structure gives an indication of the growth environment of the hailstone.

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PREFACE

This report continues the series of field program reports covering atmospheric science field research activities at the Alberta Research Council. For the first time, this report series mentions a winter research activity — a two week snowpack study carried out during March near Rushmere, B.C.

During the summer field season, extensive cloud physics data were collected by the INTERA/ARC Research Aircraft Facility. The Storm Chase, Storm Forecast and Ground Generator Assessment groups also had successful operations during this very active hail season, noted for its large hail storms and frequently reported tornado and funnel clouds.

Due to budget constraints, the operational cloud seeding area north of Township 36 was deleted and the number of seeding aircraft was reduced. The operational cloud seeding program south of Township 36 was unchanged from previous years.

Public relations activities this summer were highly visible, with tours by a Chinese delegation, ARC Board of Directors, Red Polled Cattlemen's Association, and an "invitation" tour for prominent area farmers, businessmen, government officials and the local news media. The Research Aircraft Facility was also "unveiled" at two separate press conferences conducted jointly by ARC and INTERA.

This report summarizes the various activities and data collected during the 1982 Atmospheric Sciences Program field season. The report material has been contributed by personnel of the Atmospheric Sciences Department, Alberta Research Council and INTERA Environmental Consultants Ltd. These contributions are greatfully acknowledged. Also a special note of thanks to all the area farmers who maintained precipitation measuring and sampling stations and to those throughout the province who supplied storm information via telephone surveys and hail reporting forms. A special acknowledgment is made to R. Deibert for organizing and assembling this report.

J. Renick, Manager
Weather Modification Project

SUMMARY

HAIL EXPERIMENT — Three controlled seeding experiments and 7 research missions were devoted to obtaining microphysical data in thunderstorms.

RAIN EXPERIMENT — Nine controlled seeding experiments were carried out on cumulus clouds.

SULFUR/PRECIPITATION EXPERIMENT — Between 5 and 12 September, 8 research aircraft flights were devoted to the storm inflow/sulfur experiment and sulfur plume experiment.

SCALE INTERACTION EXPERIMENT — The experiment was conducted during July, with the best data collected on 14, 21 and 29 July. Twenty-two research aircraft flights were conducted within the I.P. Krick target area during the generator operational period, 21 June to 20 August. From 8 July to 5 August, 50 generator sites were visited and 44 fuel samples collected for chemical analysis.

SNOW EXPERIMENT — Surface and upper-air measurements were made from 16 to 26 March. Five research aircraft flights also supported the experiment during the operational period.

GROUND GENERATOR ASSESSMENT PROGRAM — Twenty-two research aircraft flights were conducted within the I.P. Krick target area during the generator operational period, 21 June to 20 August. From 8 July to 5 August, 30 generator sites were visited and 44 fuel samples collected for analysis.

RESEARCH AIRCRAFT — A total of 112.1 hours in support of all summer research activities was flown by the INTERA/ARC Research Aircraft. The aircraft was out of service from 3 to 23 August for installation of the computer-based data acquisition system.

CLOUD SEEDING — During the operational period 20 June to 31 August, 29 days required cloud seeding missions. The 452.4 flight hours are considerably lower than other years because the seeding operations in the northern area were cancelled and the compliment of seeding aircraft reduced from 6 to 4. Flare usage was 3849 top flares (55 and 20 g units) and 680 (150 g) base flares. Acetone usage was 39.3 Imperial gallons.

RADAR/COMPUTER — The S-band radar operated for 122 hrs between 9 July and 12 September. The C-band operated for 1306 hrs and the X-band for 366 hrs. Four-channel S-band data were recorded on 147 tapes representing 110 hrs on 21 days. One channel C-band data were recorded on 350 tapes representing 1118 hrs on 90 days.

STORM CHASE — A storm chase program operated from 21 June to 20 August. To supplement the hail samples obtained from the chase crews, a network of 693 stations was set up to collect hail samples during the period 1 July to 15 August.

PRECIPITATION MEASUREMENT NETWORK — A volunteer-operated precipitation measuring network of 570 stations was operated from 1 June to 31 August.

STORM FORECASTING — Routine upper-air soundings were made at Calgary and Penhold. Forecasts between 14 June and 31 August were 65% correct to within 1 Convective Day Category and 73% in forecasting Hail/No Hail.

HAILFALL ACTIVITY — During the operational cloud seeding period, hail was reported in the project area on 40 days, and 2392 hail reports were received. During the hail season (1 June to 30 September), there were 49 hail days in the project area (4% above the 1957-1982 average). The 2431 hail reports during the period were 5% below average.

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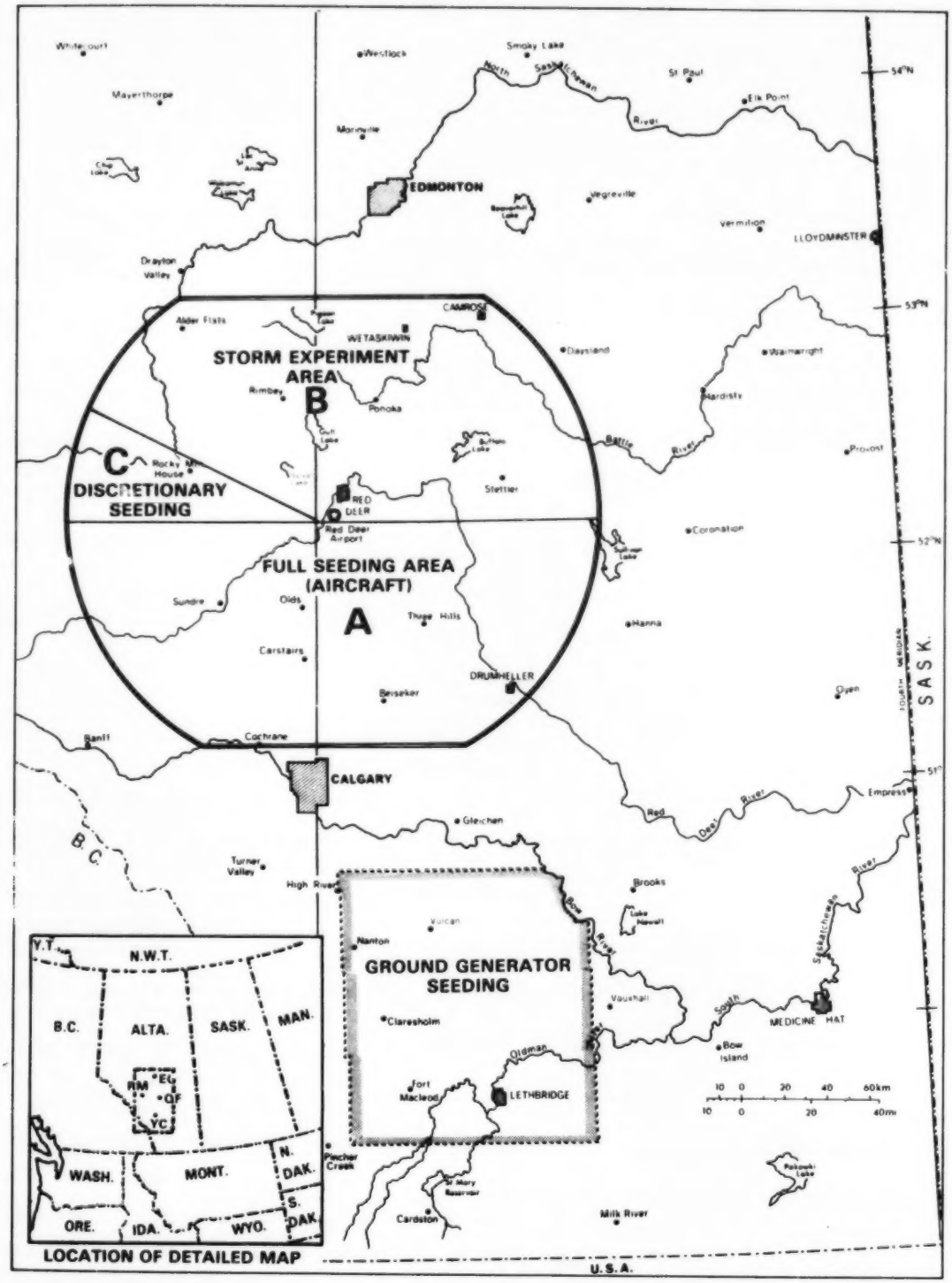


Figure 1. Atmospheric Sciences Program experiment areas. The area between Edmonton and Calgary is the principal target area of the Alberta Hail Project. The area south of Calgary is the I.P. Krick ground-based generator primary target area. (See section on Cloud Seeding for an explanation of areas A, B and C.)

INTRODUCTION

The Alberta Hail Project (AHP) is a comprehensive weather modification research program of the Government of Alberta. The Alberta Research Council (ARC), on behalf of Alberta Agriculture (the principal funding agency), acts as the central management and research agency for weather modification activities in Alberta. The Atmospheric Sciences department of ARC is responsible for program design and implementation. The department's organizational structure is shown in Appendix 1.

During 1981, the Atmospheric Sciences Program was organized into two major projects, Weather Modification and Applications. These projects were in turn divided into subprojects, some of which are further divided into specific experiments. These experiments (hail, rain, sulfur, scale interactions, snow, and ground generators) are discussed in the next section of this report. The AHP provides the mechanism for projects and subprojects to obtain data to meet stated objectives and goals of the Atmospheric Sciences Program. The AHP Field Operations (research aircraft, cloud seeding, radar/computer, storm chase, precipitation measurement network, storm forecasting and hailfall activity) are discussed following the section on Field Experiments. Appendix 2 depicts the allocation of resources to support the projects, subprojects and field experiments.

The AHP includes aircraft and ground generator cloud seeding components provided under contract by INTERA Environmental Consultants Ltd. and I.P. Krick Associates of Canada Ltd., respectively.

The Project's principal target area of 48,000 km² is centered on the radar site located at the Red Deer Industrial Airport. A second target area using silver iodide ground-based generators is located in an area south of Calgary (Figure 1).

FIELD EXPERIMENTS

HAIL

The primary objectives of the hail experiments are to document any effects of cloud seeding on hail growth by applying various treatments to individual cloud turrets in the new growth zone of Alberta hailstorms, and to determine the most effective treatment for suppressing hail. The secondary objectives are: to collect microphysical and dynamical measurements within untreated and operationally seeded thunderstorms to increase our understanding of the precipitation processes active in Alberta thunderstorms; to determine the effectiveness of present operational seeding techniques; and to compare cloud hydrometeor size, shape and phase observed by the aircraft to radar measurements of the cloud.

Controlled seeding experiments on hailstorms were designed to meet the primary objectives stated above. Such experiments involved choosing individual cloud turrets in the new growth zone of hailstorms as test clouds according to characteristics measured by the research aircraft during pretreatment penetrations, and then apply an appropriate treatment (according to a predetermined sequence) to the test cloud with a seeding aircraft. The effects of the treatment were then documented by repeated penetrations through the seeded cloud by the research aircraft. Once the seeded cloud became too intense to be penetrated, the growth and movement of its precipitation was documented by radar observations. Finally, precipitation samples were collected at the ground by crews in storm chase vehicles who provide data for linking radar observations with hail on the ground (Figure 2).

The secondary objectives were met by aircraft penetrations of natural and operationally seeded thunderstorms.

Results

Valuable operational experience was gained performing controlled seeding experiments on thunderstorms. However, problems with the data exist, as data quality, at present, appears to be poor. Some hope exists, however, that improved calibration routines will alleviate this problem. Improper sensor installation and poor quality temperature amplifiers have caused problems in the data that can probably not be rectified. An extensive investigation of data quality is recommended before any analysis of particular aircraft data is undertaken.

Furthermore, the controlled seeding experiments were not totally successful. Great difficulty was experienced in trying to find and repeatedly penetrate the seeding curtain. Our ability to track selected parcels of air must be improved. A preliminary assessment of the data suggests that the effects of seeding on hailstorms cannot yet be determined.

The data collected this summer, however, will allow documentation of the microphysical characteristics of radar echoes between 20 and 45 dBZ from natural storms and of non-echoing cloud regions. An unseeded hailstorm on 11 July 1982 was penetrated and the real-time impression of the storm indicated precipitation recycling as a source of hail embryos. This can be investigated in detail with the data collected.

RAIN

The primary objectives of the rain experiments are to document the effect of various treatments on precipitation development in cumulus clouds and to determine the

most effective treatment for rain enhancement from such clouds. These seeding experiments were rather similar to the seeding experiments conducted on hailstorms except that they were somewhat easier, as the situation was not complicated by the close proximity of a hailstorm.

Like the hailstorm seeding experiments, a test cloud was first chosen according to characteristics measured during pretreatment penetrations. (These criteria were: cloud top temperature colder than -8°C, liquid water content $\geq 0.5\ gm^{-3}$, ice crystal concentration $\leq 1\ L^{-1}$). The appropriate treatment was applied to test clouds from an aircraft flying at or near cloud top. (The treatments were: seeding with CO_2, AgI or a placebo.) After treatment, the research aircaft made numerous penetrations through the cloud to document seeding effects. The shape of the initial radar echo and its height (when radar echoes resulted from test clouds) were also important criteria for evaluating treatment effects.

Results

Nine controlled seeding experiments were carried out on cumulus clouds. During these 9 seeding experiments, 8 cumulus clouds were actually seeded. Of these 8 seeded clouds, 3 produced radar echoes with the distinctive tube-like shape (parallel to the seeding track) expected from seeded clouds (see section on Research Aircraft, and Appendix 3 for a daily listing of flights).

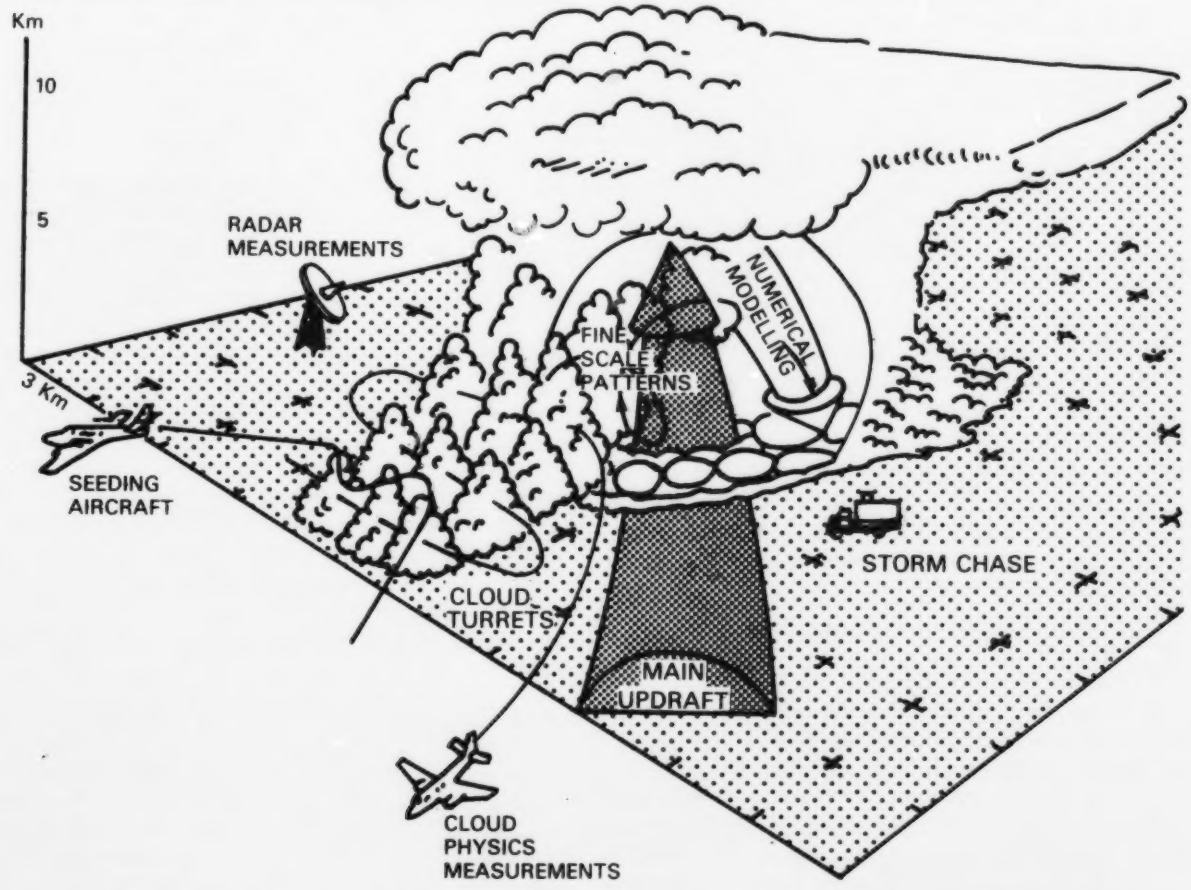


Figure 2. A schematic representation of the 1982 hail experiment. Seedability of cloud turrets in the new growth region of a hailstorm is determined during penetrations by the cloud physics aircraft. Repeated passes are made through the cloud turrets to document the growth and concentrations of ice crystals. Fine-scale radar reflectivity patterns are tracked, and subsequent hail growth is calculated using numerical models. Time-resolved measurements of the hailfall are obtained by the storm chase crew. The hailstones are analyzed to assess the seeding effects.

SULFUR/PRECIPITATION

The objective of the sulfur experiment is to determine the effect of gas plant sulfur emissions on precipitation processes in central Alberta.

Background

Considerable work has been done at ARC on the chemical composition of precipitation samples in central Alberta. The most recent data suggest that sulfur is involved in the precipitation processes, but the results are not conclusive. Preliminary statistical analyses of total sulfur emissions and crop loss to risk insurance data suggests that significant correlations exist, indicating a possible hail suppression effect. However, these correlations may simply be coincidental. More extensive and sophisticated analyses need to be conducted to rule out coincidence. The sulfur experiment was initiated by ARC to establish whether or not a cause and effect relationship exists between sulfur emissions and precipitation in central Alberta.

Approach

The approach chosen to meet the objectives was to measure aerosol characteristics in the inflow of storms located both upwind and downwind of an isolated gas plant (Rimbey). The characteristics of the cloud droplets and ice crystals above the inflow were also to be measured and a relationship between aerosol characteristics and water particle characteristics sought. Once such a relationship is established, the water particle measurements can be combined with radar and surface observations to determine the effect of aerosols on precipitation at the surface. It is expected that any link between aerosols in the storm inflows and gas plant emissions can be established by plume tracer studies.

In the event that the emissions from an isolated gas plant by themselves are not sufficient to affect precipitation processes, similar measurements will be made in the southwestern project area, where most of Alberta's gas processing plants are located, and where concentrations of sulfur dioxide and sulfates are expected to be highest.

This investigation is expected to be completed in about five years. At least three years of measurements are anticipated. The ultimate goal of the study is to develop a numerical model of the transport, diffusion and chemical activity of these emissions that can be combined with available cloud models.

Aircraft Instrumentation

The research aircraft is equipped with a PMS-ASASP-100X aerosol probe, and sulfur dioxide and sulfate filter pack sampler in addition to the meteorology, position keeping, wind, and cloud physics instrumentation.

Field Program

Between 5 and 12 September 1982, a sulfur field program that involved aircraft measurements was carried out. The two objectives were:

1. Storm Inflow and Sulfur Experiment: Measurements of aerosols and cloud water particles in the inflow of convective clouds were made at various distances (0 to 70 km) upwind and downwind of the Rimbey gas plant. Similar measurements were made in the southwestern and northwestern project area to simulate the upwind and downwind differences. Supporting data were provided by radar observations of the cloud, and ground precipitation sampling and measurements by storm chase crews. Figure 3 shows a schematic representation of this experiment.

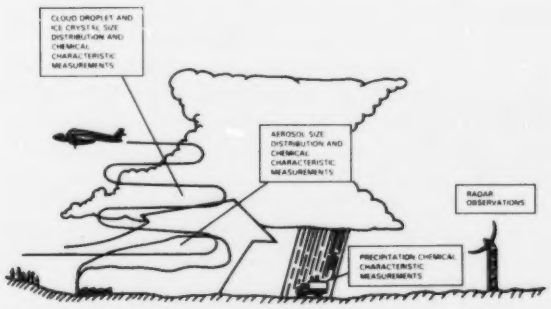

CLOUD DROPLET AND ICE CRYSTAL SIZE DISTRIBUTION AND CHEMICAL CHARACTERISTIC MEASUREMENTS
AEROSOL SIZE DISTRIBUTION AND CHEMICAL CHARACTERISTIC MEASUREMENTS
RADAR OBSERVATIONS
PRECIPITATION CHEMICAL CHARACTERISTIC MEASUREMENTS

Figure 3. A schematic representation of the storm inflow and sulfur experiment. The research aircraft made measurements of aerosols in the inflow of convective clouds and at various distances (0-70 km) upwind and downwind of the gas plant. The cloud above the inflow region was measured for cloud water particles, while ground crews collected precipitation for chemical analysis.

2. Sulfur Plume Experiment: This experiment was carried out in an attempt to explain some recent results of a statistical study on hail insurance data. Background sulfur dioxide and sulfate concentrations were obtained at 200 m above ground 20 km upwind from the Rimbey

gas plant. Subsequent samplings at the same level inside the gas plume were made at 20, 40 and 60 km downwind from the gas plant and perpendicular to the mean wind direction. Aerosol particle size distributions were also measured along the flight tracks.

Results

Because of the installation of the computer based data acquisition system, the sulfur experiments were delayed from the planned period of 1 August to 4 September 1982. As no flights were made until 5 September (see Research Aircraft section, and Appendix 3 for a daily listing of flights), the planned ground precipitation sampling support by the storm chase crews was not available. Three sulfur plume experiments and one storm inflow and sulfur experiment were conducted. A total of 14 sets of filters were collected for atmospheric sulfur dioxide and sulfate analyses, as well as meteorological and particle size distribution data. The particle size data may not be recoverable because of improper sensor installation and instrument calibration. Moreover, the dimension of the emission plume cannot be determined due to lack of proper instrumentation. However, valuable experience was gained and major difficulties were identified, so that improvements can be made in any future experiments.

SCALE INTERACTION

Introduction

The scale interaction research is useful in the interpretation of severe storm causes and effects. This research fits primarily under quantitative assessment of the Weather Modification Project, since its ultimate goal is quantitative convective precipitation forecasting.

Large (synoptic) scale atmospheric processes are known to interact with thunderstorm complexes, and to maintain some influence throughout the life cycle of these convective storms. This influence is thought to affect storm initiation, complex size, total energy and intensity, storm regeneration, and to some extent, the eventual decay of such storms. Distinct measures of these effects are difficult to identify because they are masked by (a) diurnal influences of surface heating, and (b) a subsequent major energy source from latent heat of condensation. Here, a distinction should be drawn between individual mesoscale thunderstorms, and that region (or cloud cluster) encompassing several storms in various stages of their life cycle; i.e., the subsynoptic scale storm complex, which might include regions as large or even larger than the AHP operations area.

Capping Inversion

If synoptic processes are significant in the initiation of thunderstorms, they should cause measurable thermodynamic changes to the storm-complex environment. Furthermore, these results should be most noticeable for the more severe thunderstorm systems. Frequently, a signal for severe thunderstorm formation in Alberta (and elsewhere) is the occurrence of a capping inversion in the temperature (and often moisture) profile at about 1 km above ground (normally about 800 mb in Alberta). Beebe and Bates (1955)[1] suggested that such capping inversions were adiabatically removed (cooled) by synoptic scale ascent prior to tornado-producing severe storms. Convincing proof of this has never been shown, partly because such ascent occurs over very broad (synoptic scale) regions, while severe thunderstorm complexes tend to be confined to much smaller (subsynoptic or smaller) scale regions. More often than not, severe storm complexes are surrounded by relatively cloud-free skies where ascent supposedly is still occurring.

Scientific Hypothesis

The current Capping Inversion Study (CIS) is formulated around the new hypothesis:

> "that the cascade of energy from the larger scales of motion due to friction, provides eddy kinetic energy to the subsynoptic (or even meso) scale; this leads to (horizontally) differential lifting of the air mass, adiabatic cooling, and subsequent destabilization over 'preferred regions', rather than the whole air mass."

The CIS experiment was designed as one step towards testing this hypothesis before beginning detailed kinetic energy budget analyses of severe storm environments. The analyses will use subsynoptic scale upper air data from the Cooperative Convective Precipitation Experiment (CCOPE, Montana, 1981), in which ARC participated, and from the Severe Environmental Storms and Mesoscale Experiment (SESAME, Oklahoma, 1979).

Logistics

The technical objective of the 1982 CIS experiment was simply to measure the sequence of low-level thermodynamic changes (particularly near the capping inversion) 'prior to' the formation and/or approach of a severe storm complex. Three vans were equipped with sounding units, using the new TS-3A ADAS (Airsonde) sounding systems with optical theodolite interface. Operations required the deployment of one such unit to the (predicted) storm complex region for one or more soundings before clouds attained the cumulus congestus (TCU) stage. Not

[1] Beebe, R.G. and F.C. Bates, 1955: A mechanism for assisting in the release of convective instability. Mon. Wea. Rev., Vol.83, p.1-10.

surprisingly, this was problematic, simply because of the inherent difficulty in forecasting on such a small scale. The remaining two units usually completed a line along the forecast storm complex track spaced approximately 50 to 80 km apart (Figure 4).

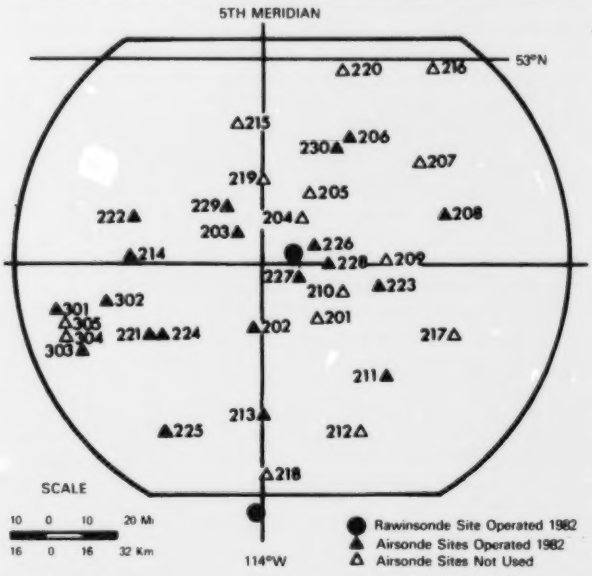


Figure 4. Location of upper-air sites.

Results

Operations were planned for July only, when capping inversions and severe storms tend to be most frequent. In this sense, nature was uncooperative. Nevertheless, meteorological requirements were satisfactory on several successful CIS operational days, the best of which were 14, 21 and 29 July, when severe thunderstorm complexes moved through the AHP operations area. Large hail and/or tornadoes were also reported on these days. CIS operations were also carried out on several less severe storm days with only weak inversions. Appendix 4 lists the times, locations of all operational CIS Airsonde and rawinsonde soundings and surveyed upper air sites.

Prestorm cooling of the capping inversion can be shown on at least two of the three major days. Detailed analyses will be carried out this winter, then compared with similar situations in the CCOPE and SESAME data. Results from kinetic energy budget analyses of the Montana and Oklahoma data should ultimately be transferrable to the Alberta CIS cases.

The next step in this experiment is to investigate topographic effects and how these relate to the formation of capping inversions over the Alberta foothills. Any synoptic effects on the severe storm environment are intricately related to, and complicated by, topographic effects. Plans are to deploy four mobile upper air units to the Limestone Mountain area (some 100 km southwest of Red Deer) during mid-July 1983. These mobile soundings, together with coincidental rawinsonde releases at Rocky Mountain House and Red Deer, will sample the spatial variability of subsidence warming and drying due to flow over the major Rocky Mountain barrier. They will also sample suspected low-level cooling and destabilization due to secondary orographic flow over smaller mountain barriers such as Limestone Mountain (the area around Limestone Mountain is known to favor severe storm genesis). These two factors, in combination with similar synoptic effects, are thought to be of prime importance in the formation and breakdown of the capping inversion. The planned 1983 soundings will also supplement sparse 1982 CIS data for determining the sequence of thermodynamic changes to capping inversions.

SNOW EXPERIMENT

The objective of the snow experiment is to gather physical evidence of the modification potential of wintertime orographic clouds over the Rocky Mountains of southern Alberta.

Surface and upper-air field measurements were performed by the Alberta Research Council from 16 to 26 March 1982. Meteorological guidance was obtained in a coordinated effort with the Atmospheric Environment Service in Edmonton. Of five research aircraft flights, only the flight on 23 March obtained measurements within precipitating clouds. Eighteen upper-air soundings were obtained from the site at Rushmere, B.C. (Figure 5). Additional support information consisted of time-lapse and still cloud photographs, some snow crystal examination and automatic weather station measurements.

For more details on the project, the reader is directed to an interim report by Krauss *et al.*, (1982) and to a final report expected in early 1983.

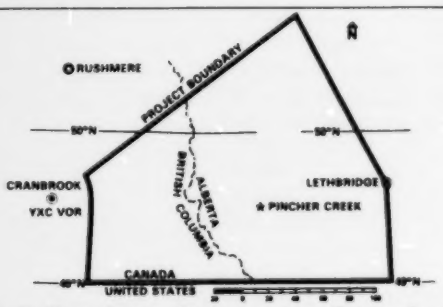


Figure 5. The Snow Project area. Research aircraft flights were made along specific tracks within the project boundary to obtain in situ observations of the cloud hydrometeors and thermodynamic structure.

GROUND GENERATOR ASSESSMENT PROGRAM

The Ground Generator Assessment Program (GGAP) completed its second season of operations. GGAP is intended to evaluate the ability of I.P. Krick ground generator networks to seed clouds.

Irving P. Krick Associates of Canada installed and operated a network of ground-based silver iodide generators south and east of Calgary (Figure 1). This network consisted of 66 sites and 88 generators of the coke and arc type. The generator operational period was 21 June through 20 August. Table 1 summarizes generator operations.

Three CR 21 automatic weather stations were installed within the general GGAP study area (Figure 6). The purpose of these stations was to supplement existing Atmospheric Environment Service stations to provide hourly wind data for silver iodide pool analysis. Table 2 summarizes CR 21 operations.

From 8 July to 5 August, 50 ground generator sites were visited to assess the reliability of ground generator network operations — 44 fuel samples were collected. Sites visited and fuel samples collected are listed in Appendix 5. Twenty of these samples will be analyzed for silver and soluble salts by the ARC Chemistry Analytical Group.

A total of 22 research aircraft flights and 44.1 hrs of aircraft time were logged in support of GGAP (Table 3). Of these, two were background measurement flights, six were pool mapping flights and three were pool mapping and convective cloud penetration missions.

An interim report on the GGAP 1982 field program was published on 15 November and a final report, including analyses and results will be published by 31 March 1983.

Table 1. Summary of ground generator operations in 1982. Operations were conducted on 40 days of the 61-day contract period.

	COKE GENERATORS HOURS OPERATED	ARC GENERATORS HOURS OPERATED	TOTAL OUTPUT (g)
June	238	707	6963
July	528	1092	12718
August	404	655	9996
1982 Totals	1170	2454	29677

Table 2. CR 21 sites operated during GGAP 1982 field program.

Site	Location	Operational Period
CR1 #37	Champion (SW 29 14 23 W4)	July 20 - August 10
CR2 #56	Millarville (NW 10 21 3 W5)	July 5 - August 9
CR3 #48	Bassano (SW 5 22 19 W4)	July 11 - August 5

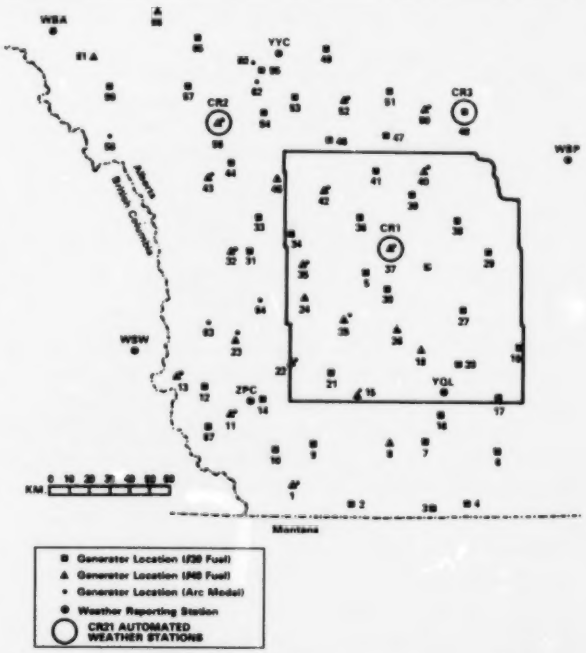


Figure 6. The site locations of ground-based, silver iodide generators in the GGAP area. The network consisted of 66 sites and 88 generators of the coke and arc type. Three sites were also equipped with automatic weather stations.

FIELD OPERATIONS

RESEARCH AIRCRAFT

The INTERA/ARC Research Aircraft Facility, a specially equipped Cessna 441 Conquest, played a key role in the 1982 field programs. A total of 112.1 hrs of research flight time was compiled.

Several clearly defined scientific objectives received aircraft data support. A brief description of these follows:

Hail Experiments: Controlled seeding experiments on hailstorms to document the effect (on hail growth) of applying various treatments to individual cloud turrets in the new growth zone, and to determine the most effective treatment for suppressing hail.

Rain Experiments: Controlled seeding experiments on towering cumulus clouds to document the effect of various treatments on rain production and to determine the most effective treatment for rain enhancement.

Ground Generator Assessment: Flights within the I.P. Krick target area designed to map the areas of artificial ice nuclei emanating from ground generators and to penetrate convective clouds to determine the concentrations of ice crystals within treated and untreated clouds.

Scale Interaction Experiment: Investigation of low-level capping inversions to determine the sequence of thermodynamic changes in severe storm environments.

Sulfur Experiment: An experiment to measure the size, concentration, and chemical composition of aerosols emanating from gas plants and to determine the effect of gas plant sulfur emissions on precipitation processes.

Snow Experiment: To gather physical evidence of the modification potential of wintertime orographic clouds over the Rocky Mountains of southern Alberta.

Thunderstorm Experiment: Fall-back experiments designed to collect microphysical and dynamical measurements within untreated and operationally seeded thunderstorms.

Data Monitoring: Flights designed to test sensor performance and monitor data quality.

The research aircraft flights are summarized according to objective in Table 4. A listing of each flight objective with take-off and landing times appears in Appendix 3.

On the evening of 3 August, the aircraft was removed from service for the installation of the newly developed computer-based data acquisition system. Data monitoring flights with the new data system began on 23 August and sulfur flights were performed from 5 to 12 September. The computer-directed system promises to expand capabilities in data acquisition, recording and display (see Discussion section).

Table 3. Daily listing of research aircraft flights in support of GGAP. Flights are labelled as successful (S), unsuccessful (U), or test (*).

DATE	FLIGHT HOURS	FLIGHT OBJECTIVE TEST	MAPPING	PENETRATIONS	COMMENTS
June 20	0.4	*			QF Tower Fly By
June 21	1.7	*			"Sniffing" of GG
June 24	1.4		U		Ceiling Too Low
June 26	2.3		S		Background Measurement
June 27	3.0		S		Background Measurement
June 29	1.7	*			"Sniffing" of GG
June 30	1.6		U		NCAR Problem
July 2	0.3	*			QF "Sniffing"
July 3	0.4	*			QF "Sniffing"
July 3	1.7	*			"Sniffing" of GG
July 4	3.4	*			"Sniffing" of GG
July 9	0.8		U	U	NCAR Problem; No TCU
July 9	0.4	*			A/C Power System Test
July 12	3.0		S	U	Good Mission; No TCU
July 21	2.6		S	S	Good Mission
July 25	3.1		S	S	Good Mission
July 28	2.6		S	U	Good Mission; No TCU
July 31	2.1		S	U	Only 3 generators operating: 2" diamond
August 2	2.3		S	U	ARC request for IPKA Targetting
August 2	2.8		S	U	ARC request for IPKA Targetting
August 3	3.3		S	S	Good Mission
August 3	3.2		S	U	Many NCAR problems but some good data collected

Table 4. Summary of research aircraft flight-time according to experiment.

Experiment	No. of Flights	Total Hours
Hail	3	7.1
Rain	9	15.1
Ground Generator	23	44.1
Scale Interaction	2	2.7
Sulfur	9	14.5
Thunderstorm	7	10.1
Data Monitoring	18	18.5
	71	112.1

CLOUD SEEDING

Introduction

The 1982 cloud seeding program was similar to that of previous years (see, for example, the 1979-1981 Field Program Reports). Several significant operational changes were incorporated into the 1982 program, including:

a) reduced aircraft complement;
b) reduced operational seeding area;
c) occasional use of one seeding aircraft as a support aircraft on missions involving the research aircraft;
d) modifications to the cloud seeding guidelines;
e) the development and operational use of an improved silver iodide-acetone storage, mixing, transfer and refuelling system;
f) the establishment of a permanent INTERA base facility at Penhold.

The INTERA Environmental Consultants of Calgary again conducted the cloud seeding operation, under contract with the Alberta Research Council. As in 1981, the operational cloud seeding period was 20 June through 31 August, and the INTERA aircrew training course was conducted from 15 to 19 June. In addition, one cloud seeding aircraft with crew was available from 1 June to support the activities of the research aircraft, and similarly one seeding aircraft with crew was standing by from 1 to 12 September to support research aircraft missions.

Cloud Seeding Area and Seeding Guidelines

As a result of budgetary constraints, the operational cloud seeding area was decreased in size from that of 1981. Figure 1 shows the 1982 Cloud Seeding Area Plan. Operational seeding was carried out only in area A, while in previous years all of areas A, B and C were operationally seeded. The aircraft complement was reduced to four seeding aircraft (plus one backup aircraft) from the complement of six cloud seeders in 1981.

The cloud seeding guidelines were also modified to account for the changes in project area. Basically, the guidelines state that all storms in area A meeting certain criteria be seeded (see section on Discussion, 1981 Field Program Report), while no operational seeding be carried out in area B. Operational seeding could be carried out in area C, at the discretion of the ARC Cloud Seeding Monitor. Also, the research aircraft could conduct experiments in any of the three areas (A, B or C) and an operational seeding aircraft could be assigned to support certain research aircraft missions. At the discretion of the Cloud Seeding Monitor, certain operational seeding requirements could be temporarily waived to facilitate research aircraft experiments and/or seeding aircraft support of such experiments.

Cloud Seeding Logistics and Seeding Systems

The cloud seeding logistics remained unchanged from those of previous years. The seeding technique uses various pyrotechnic devices to deliver artificial ice nuclei (AgI) into select regions of hailstorms. Droppable flares are used for cloud top seeding to inject seeding material into the new growth region of hailstorms. End-burning flares, or acetone generators, are burned below cloud base along the upwind portion of the subcloud inflow and updraft region. The updraft then carries the seeding material upward into the storm. For further details, see Barge *et al.* (1976)[2].

Two types of top flare systems were used or cloud top seeding in 1982 — the old, reloadable flare system using NEI (Nuclei Engineering Inc.) TB1 55 g AgI droppable flares, and the new, nonreloadable pencil flare system using NEI TB1 20 g AgI droppable flares. The pencil flares are released approximately once every five seconds, compared to a rate of about once every 20 seconds for the old, top flares. Pencil flares likely allow greater dispersion of seeding material into hailstorms. Because of this, the pencil flare system is now being emphasized at the AHP and the older flare system is being phased out.

For cloud base seeding, the flares used were once again the 150 g AgI end-burning fusees, with a burn time of four minutes. Some inconsistencies in the mixture of these flares were discovered, and a few flares actually exploded during seeding. The bad batch was identified and sent back to NEI for testing. For the second year, acetone generators were used operationally in cloud base seeding. These generators burn a 2% solution of AgI in acetone. Each acetone equipped aircraft carries two generators, and each generator burns solution at the rate of 1.7 Imperial gallons per hour.

[2] Barge, B.L., F. Bergwall, G.G. Goyer and J.H. Renick, 1976, Fine scale structure of convective storms-implications for cloud seeding in Alberta. Atmospheric Sciences Division, Report 76-3, Alberta Research Council, Edmonton, 19 pp.

All four seeding systems were reliable in 1982. The technical problems encountered in 1981 with the acetone generators were resolved. In particular, a completely new acetone solution storage, mixing and refuelling system was designed for the 1982 operation. This system worked well and is now an integral part of the acetone generator seeding system.

Appendix 6 lists the seeding aircraft and the seeding systems that were mounted on each aircraft in 1982. Aircraft GBLB and GELL each served as backup aircraft at different times during the summer. The equipment listed in parentheses details the options that could readily have been mounted in place of the corresponding primary systems, had the need arisen.

Facilities

A new facility in 1982 was the INTERA hangar and laboratory complex. This facility conveniently houses the seeding aircraft, the research aircraft, and the supporting equipment and personnel. All of INTERA's operations in Penhold, and in particular its AHP operations, are now permanently based in this new hangar facility.

Personnel

Appendix 6 contains a list of INTERA personnel involved in the 1982 cloud seeding and research aircraft programs. The INTERA radar controller/meteorologist assigned full-time at Penhold is continuing work under the joint supervision of the Atmospheric Sciences Department of ARC and INTERA.

Seeding Aircraft Flights and Flare Usage Summary

Table 5 summarizes the seeding aircraft operations for 15 June through 31 August 1982. Missions (255) and flight hrs (452.4) are down from the corresponding 1981 totals of 379 and 690.6. Similarly, the flare usage is down from that of 1981. The totals in Table 5 include those flights in which a seeding aircraft flew in support of a research aircraft mission. Between 15 June and 31 August, 12 such missions totalling 24.7 hrs were flown. Several support missions were also flown between 1 and 14 June and again between 1 and 12 September. Appendix 9 contains a daily summary of hailstorms and cloud seeding activities. During the 73 days from 20 June through 31 August 1982 (the operational period), there were 29 days with cloud seeding, 21 days with patrol only and 23 days with no flight operations. The smaller seeding area meant fewer seeding days in 1982, but there were more patrol only days in 1982 than in 1981. Appendix 6 summarizes the numbers and flight hrs of the various types of missions flown by the seeding aircraft during 1982. Four separate time periods are examined: pre-operational period (1 through 14 June), training period (15 through 19 June), operational period (20 June through 31 August), and post operational period (1 through 12 September). During the operational period, 365.5 flight hrs were devoted to seeding or patrol missions. This represents 80% of the total flight time of 437.4 hrs during 1982 operations.

Table 5. Summary of 1982 aircraft cloud seeding operations: June 15 - August 31.

Aircraft	Missions	Hours	Large Top Flares Dropped	Pencil Flares Dropped	Base Flares Burned	Acetone Burned (Gal)
HS1	25	50.3				26.1
HS2	50	101.1	534		306	
HS3	35	53.9		433		13.2
HS4	89	148.4		2,396	172	
HS5	37	64.8	486		74	
HS6	19	33.9			128	
Total	255	452.4	1,020	2,829	680	39.3

RADAR/COMPUTER

Radars

Operating schedules and facilities were similar to those of the 1981 field program. The C-band radar was available throughout the program while the S-band radar was available for the latter half. In general, the C-band radar provided the normal surveillance data; the S-band radar provided information only during research activities.

S-band

During the interval between the 1981 field program and the commencement of the 1982 field program, unsuccessful discussions were held with EEC (Enterprise Electronics Corporation) with regard to rebuilding the magnetron modulator. It was therefore decided to undertake the design, construction and testing of a new modulator in house. The newly designed modulator tested satisfactorily and was installed into the transmitter by 25 June. A report of this design will be available shortly.

A lightning strike near the radar facility on 1 August damaged the new modulator and the remote monitor. Repairs to both systems were completed within 7 days.

The original double side band, high noise figure receivers were replaced with a set of single side band, low noise figure receivers. These receivers were in place and worked to design specifications throughout the 1982 program. The design is documented in an ASD report, "An S-band low noise receiver" (G. Cardinal, February, 1981).

Between 9 July and 12 September the transmitter was used for 122 hrs.

The antenna drive mechanism suffered aging difficulties throughout the summer. The slow speed clutch failed again and was replaced with a modified electronic drive control while the old clutch was returned for an in-depth investigation of its failure. At the close of season the main drive was dismantled for refurbishing of its gears and bearings.

C-band
A new slip ring assembly could not be delivered in time for the field season commencement,.thus old fingers were refurbished with new contacts. The pedestal was thus operational throughout the season.

A new magnetron (LT7156A) was installed in July. The old one (installed in May 1981) had operated for 1700 hours.

The C-band radar, available 24 hrs with nightly calibration, totalled 1306 hrs of operation.

X-band
The transmitter thyratron failed mid season; an on-hand spare returned the system to full operation within hours of the failure. Four transponders failed during the season. The failures, coupled with the reduced number of aircraft, occurred over a sufficient period that each seeding aircraft always had a transponder when needed. The X-band operated for 366 hrs.

Communications
The master control console was modified by relocating the telephones, adding variable intensity lighting to the writing areas and installing an isocom to provide FM communication to the research aircraft via the storm chase room's FM transceiver.

A fibre optic link broke during the off season and was flown (over a 3 day period) to Ottawa and back for repair before the season started. High winds damaged the AM antenna tower, which in turn was repaired, extended by 3 m and guyed for additional strength.

Field Site Computer System
During 1981 minor problems became apparent in the operational computer program. The problems were corrected and improvements were made in 1982 to simplify computer usage. Operational support for the research aircraft was provided by an additional real-time display. A new computer, a PDP-11/44, was installed at the field site for flood forecasting work.

Operations Penhold/Edmonton
The reliability of the radar systems continued to improve allowing an operations procedure identical to the previous year.

The PPI thresholds of both the S- and C-band radars were adjusted to give an iso-contoured display.

Four channel S-band data were recorded on 147 tapes representing 110 hrs on 21 days.

One channel C-band data were recorded on 350 tapes representing 1118 hrs on 90 days. The daily radar and computer tape logs are listed in Appendix 7.

Some dual frequency (S- and C-band) data without synchronized antennae are available.

Tape transfer to Edmonton via ASD personnel and auto transfer of other data over the computer network at 0100 hrs each day allowed all data to arrive in Edmonton for timely analyses. Information upon arrival in Edmonton followed the same procedure as last year.

STORM CHASE
A storm chase program was operated during the period 21 June to 20 August 1982. The primary objective of the program was to obtain measurements for the physical assessment and inadvertent weather modification projects. Three instrumented vehicles were directed underneath the high reflectivity zones of hailstorms to obtain sequential, time-resolved hailstone samples, rain samples and rainfall rate measurements. The hailstones collected were quenched in heptane at dry ice temperature to preserve the crystal structure. The hail samples provide information on the changes (with time) in the size distribution, axial-ratio, internal structure, embryo type, isotope content and chemical composition. From the rain samples, the chemical composition of rain can be obtained, providing information on possible seeding effects.

During the program period, 319 time-resolved hail samples (from 9 hail days), 81 hail ground samples (from 10 hail days), and 155 rain samples (12 storm days) were obtained (see Table 6). On 10 storm days, rainfall rate information was also collected. Three hail days (30 June, 21 July and 11 August) were very well documented with over 100 hail samples obtained.

Table 6. Summary of the 1982 precipitation samples collected.

Date	Mobile Samples					Network Samples	
	Sequential Samples	Ground Samples	Rain Samples	Rainfall Rate	Maximum Size of Sequential Samples	Total	Maximum Size
June 30	83	4	43	Yes	Grape	23	Golfball
July 6	-	-	1	No	-	-	
July 11	-	8	-	No		5	Walnut
July 12	-	-	8	Yes	-	1	Pea
July 14	11	-	6	Yes	Shot	5	Pea
July 17	-	-	4	Yes	-	-	
July 21	61	32	13	Yes	Walnut	114	Larger
July 23	-	-	-	-	-	2	Pea
July 25	26	-	19	Yes	Grape	10	Grape
July 27	-	-	-	-	-	1	Shot
July 29	27	2	15	No	Walnut	13	Walnut
July 31	20	3	12	Yes	Pea	2	Pea
August 1	9	3	3	Yes	Pea	18	Walnut
August 2	-	4	-	-		15	Grape
August 3	-	4	-	-		2	Pea
August 11	80	17	26	Yes	Walnut	59	Walnut
August 15	2	4	5	Yes	Shot	2	Pea

To supplement the samples obtained from the chase vehicles, a network of 693 volunteers within a 13,400 km² area of Red Deer (Figure 7) was established from 30 June to 15 August to collect time-integrated hailstone samples from the ground. These samples were picked up from the volunteers by the chase crews on no-hail days. In total, 280 samples (from 15 hail days) were obtained from the volunteers (Table 6). These samples will be analyzed for isotope content, crystal structure and embryo type.

PRECIPITATION MEASUREMENT NETWORK

A volunteer-operated precipitation measuring network of 570 stations was established over a 33,700 km² area (Figure 8) to collect daily rainfall measurements. The network was set up in May and maintained from 1 June to 1 September. Over eighty percent of the station operators returned completed rainfall records for the three months. The precipitation maps for June, July, August, and the three month cumulative totals are presented in Appendix 8. The large precipitation amounts observed in June and July are from rain storms occurring during the passage of "cold low" systems through the area.

All volunteer stations were supplied with a wedge-type rain gauge, color-coded monthly rain records, postage paid envelopes for returning the records and a folder for storing the supplies and instructions. All station operators were instructed to record the amount of precipitation noted in the rain gauge at 0800 MDT each day.

STORM FORECASTING

The Storm Forecast Group increased its commitment to field operations during 1982. Weather office and upper-air services were maintained for virtually a full month longer over the summer period, primarily in support of the research aircraft development. Additional upper-air support was provided for the snow experiment during March.

New operational activities included the Capping Inversion Study (CIS, described elsewhere in this report), which was carried out by the group during July. As well, a vastly improved and automated forecast procedure was tested on the Meteorological Data Facility, then made semi-operational in time for the extended field operations in early September.

Weather Office

With the help of three summer assistants, full weather office support was provided from 7 June through 12 September. An assistant was available for each of two daily shifts, 0630-1415 and 1315-2130 MDT. During July, the morning shift commenced at 0600 MDT to support CIS operations.

Atmospheric Environment Service (AES) teletype circuits and a weather facsimile circuit provided surface and upper-air data, analytic and prognostic charts and low resolution weather satellite imagery. Back-up data, including Spectral Prog grid point data from the Canadian Meteorological Centre in Montreal, were provided by three additional teletype circuits connected to the Meteorological Data Facility in Edmonton. Access was via the ARC computer DECNET system. Formatted data output such as surface trend sheets, essential for the Statistical Forecast Research activity, are available on this facility.

Unfortunately, planned software for archiving both raw and decoded teletype data on this facility could not be implemented during 1982. One additional student was available for limited software development and for help with CIS operations. Software development included an improved rawinsonde wind program and a crude but automated map plotting routine.

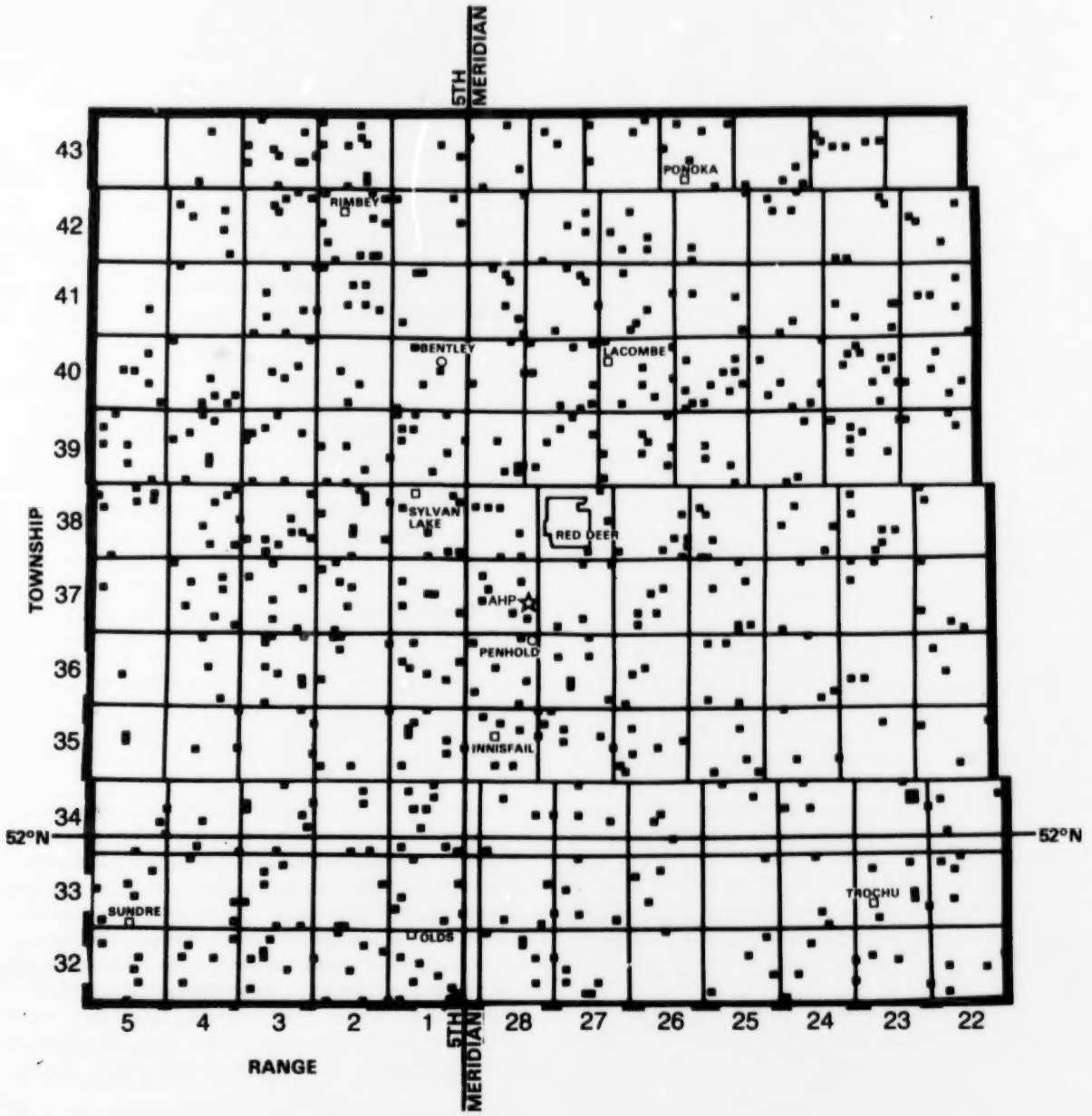


Figure 7. The 1982 hailstone collection network. This network of 693 volunteers was set up to supplement the samples obtained from the storm chase crews. The hail samples will be analyzed for isotope content, crystal structure and embryo type.

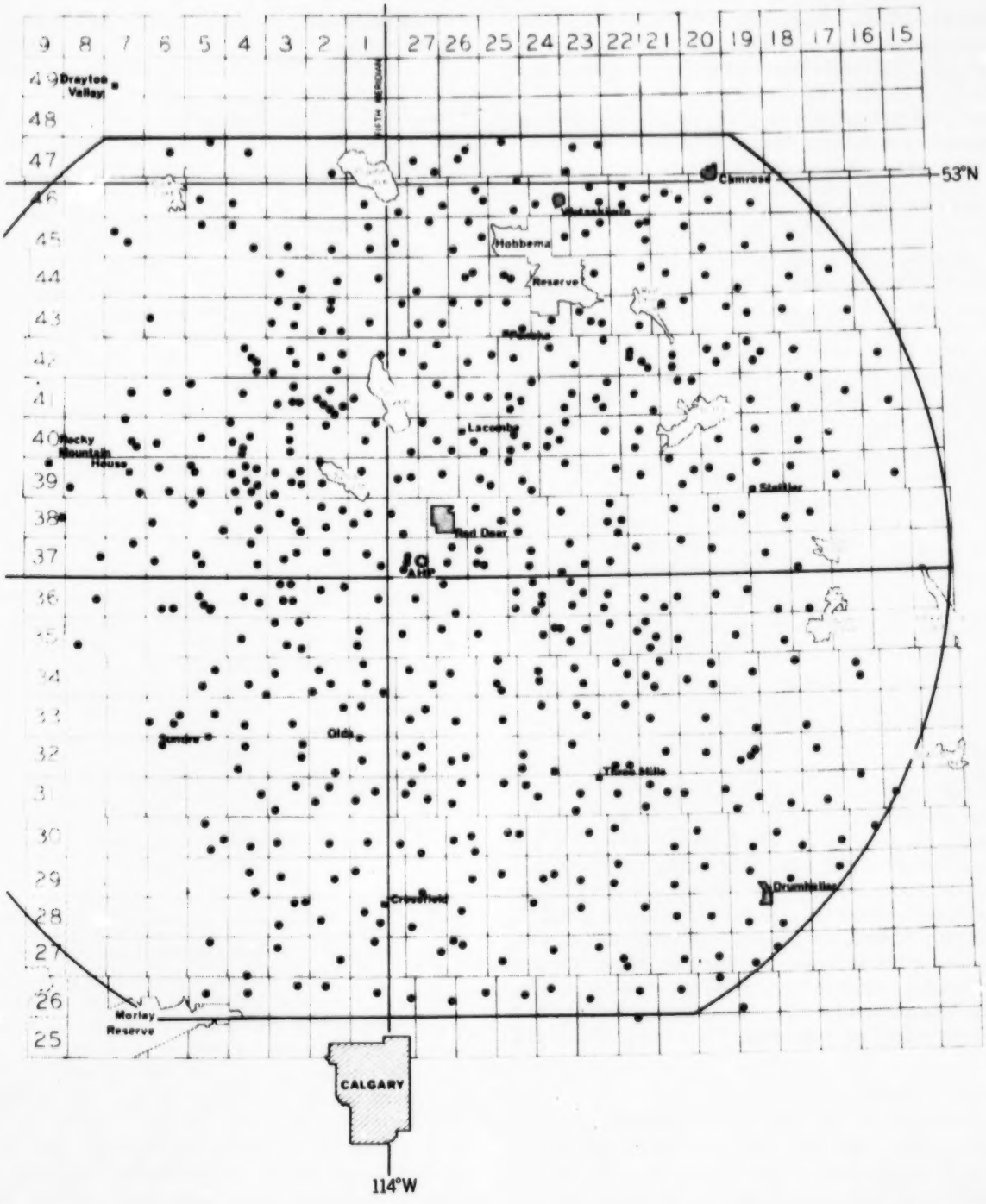


Figure 8. The 1982 precipitation recording network. The 570 volunteer stations (within a 33,700 km² area) recorded daily rainfall amounts during June, July and August.

The AES Alberta Weather Center in Edmonton again provided forestry weather data and the EGDEX forecast. The latter is a key element used in the Synoptic Index computation. In return, the ASD weather office provided AES the CAQF (Red Deer) and CYYC (Calgary) soundings via teletype, and daily forecast summaries via telecopier.

Upper-air Operations

Rawinsonde operations at the Red Deer and University of Calgary (CYYC) sites were staffed by three returning summer assistants and three trainees.

Two operational soundings per day were commenced on 14 June. Earlier release times of 0515 and 1515 MDT at Calgary, and 0615 and 1515 MDT at Red Deer, supported CIS operations which required morning soundings by 0730 MDT. An additional 11 rawinsonde soundings were provided during July to augment the CIS data. Because of the unavailability of 403 MHz radiosondes (used with the older METOX rawinsonde equipment), remaining stocks of these sondes were shelved for future research experiments and the METOX equipment at CYYC was removed. In its place, the 1680 MHz Mobile Rawinsonde (MORAS) System was moved to Calgary for the summer. The same system was used in southeastern British Columbia during March to support the snow experiment.

The new Airsonde (TS-3A ADAS) systems were used exclusively for CIS during July. Fortunately, only three units were required for CIS, as one other was inoperative when received from the manufacturer, while the fifth performed intermittently. The three good units, including optical theodolite systems, were installed in ¾ ton vans for mobile deployment. For CIS purposes, where low-level data (below 600 mb) were most critical, the ADAS units proved quite adequate, although only one unit was able to access wind data automatically. Signal strength of the 403 MHz Airsonde is weak at high altitudes, often resulting in missing data above 400 mb. However, reliable data were occasionally received beyond 150 mb. A summary of all Airsonde and rawinsonde releases is provided in Table 7. A total of 551 upper-air releases were made during 1982.

Instrumentation

Three Warren-Knight optical theodolites were purchased during 1982. These have been modified for use with the TS-3A ADAS (Airsonde) upper-air systems. The Airsonde systems were operationally tested throughout the summer, including several inter-comparison flights with rawinsondes, frequency tests and the CIS operations already noted.

The new CAQF auto-tracking 1680 MHz rawinsonde system (received in late 1981) performed flawlessly. Three of the automated CR-21 surface weather stations were used in the ground generator project south of Calgary, while the fourth was extensively tested, first in British Columbia during the March snow experiment, and then throughout the summer at the ASD weather office.

Table 7. Summary of rawinsonde and Airsonde releases during 1982.

Rawinsondes	CAQF	CYYC	Rushmere, B.C. (Snow)	Totals
Training	15	9		24
Intercomparison	7			7
Operations	156	143	18	317
C.I.S. Support	7	4		11
Abandoned	6	6		12
Totals	191	162	18	371
Rejected Instruments	25	15		40

Airsondes	CAQF	CIS 1	CIS 2	CIS 3	Totals
Training & Practice	14	4	0	8	26
Equipment Test & Intercomparison	7	3	2	2	14
Frequency Test Flights	2	6	5	5	18
Operations Flights	14	36	29	43	122
Totals	37	49	36	58	180

Forecasting

Forecast support for field operations was provided from 14 June through 31 August. A reduced weather briefing service was provided from 6 through 13 June, and again from 1 through 12 September. Three weather briefings were presented daily: at 0850 MDT to CIS operations personnel (July only), at 0915 MDT to key operations personnel for daily planning and the main briefing at 1100 MDT for all project personnel. Update briefings were frequently provided around 1415 MDT. Forecasts included the anticipated Convective Day Category (CDC, defined in Table 8), cloud types, bases and tops, cloud seeding heights and temperatures, thunderstorm and thunderstorm 'complex' motions, and most likely region of storm complex initiation. The latter was of particular interest to the CIS and storm chase operations.

Table 8. Definition of AHP convective day categories, valid from 1700 UTC (briefing time) to 1200 UTC the following morning.

CDC	Maximum Intensity of Convective Weather
-3	No deep convection
-2	ACC, TCU, or CB at 2 or more surface weather stations
-1	Scattered showers (1 or 2 stations)
0	A thundershower without hail, or widespread showers
1	PEA or SHOT* maximum hail size
2	GRAPE* maximum hail size
3	WALNUT* maximum hail size
4	GOLFBALL* maximum hail size
5	LARGER THAN GOLFBALL* maximum hail size

*Two or more verifiable reports are required to qualify in each hail category.

The single-valued Synoptic Index of Convection (S_c10) proved useful for a fifth consecutive summer, while there was increased interest in the extended (36 hour) outlook for next day planning. The S_c10 is subjectively modified by the forecaster to provide a forecast CDC for the day. Experience has shown that hail (CDC > 0) should be forecast when the $S_c10 > 1.5$, and rarely, if ever, when the forecast $S_c10 < -1.5$. In fact, the S_c10 consistently shows more success than the forecaster in correctly predicting the Hail/No Hail stratification.

Table 9. Verification of forecast CDC (subjectively modified forecast S_c10) categories, 14 June - 31 August 1982. Linear correlation coefficient = 0.62. Dashed lines show forecasts accurate to within ±1 category.

CDC OBSERVED	FORECAST CDC -3	-2	-1	0	1	2	3	4	5	Totals
-3	1	–	4	–	–	–	–	–	–	5
-2	2	1	–	1	–	–	–	–	–	4
-1	1	–	4	1	2	–	–	–	–	8
0	1	1	4	6	5	4	1	1	–	23
1	–	1	2	–	5	4	1	–	–	13
2	–	–	2	2	4	3	2	–	–	13
3	–	–	–	–	1	3	4	–	–	8
4	–	–	–	1	–	1	1	–	–	3
5	–	–	–	–	–	1	–	1	–	2
Totals	5	3	16	11	17	16	9	2	0	79

Haildays in period: 39 days = 49.4%
Correct category: 24 days = 30.4%
Correct within one category: 51 days = 64.6%
Correct within two categories: 71 days = 89.9%

The forecast verification Tables 9 and 10 verify only the subjectively modified forecast CDC (not S_c10 forecasts) and Hail/No Hail decisions respectively. CDC forecasts were correct within one category 65% of the time (down from 73% in 1981). Hail/No Hail was correctly forecast 73% (down considerably from 85% in 1981). Hail days were correctly forecast for almost 80% of the operations period (31 of 39 hail days in the 79-day period). The fact that scores were lower overall than in previous years may be attributed in part to rather erratic weather patterns, a relatively cool, wet summer and consequent difficulties in estimating low-level moisture for convective parcels. See Appendix 11 for the daily meteorological and storm data summaries.

The S_c4 index (utilizing only 4 compared with 10 covariates for the S_c10) has now been tested over two summers. It showed slightly less accuracy than the S_c10 as a single-valued predictor. However, the S_c4 is much simpler to compute, has now been semi-automated (on the Meteorological Data Facility) and yields a contoured map of the field of Synoptic Index rather than just one value. The areal version of the S_c4 was tested operationally for the first time during the extended operations period, 1 through 12 September. Preliminary results look impressive. The added spatial dimension provides an objective forecast of storm complex size and region of maximum intensity, in addition to the maximum degree of intensity. When combined with even a rough estimate of storm motion, regions of storm initiation can now be inferred. Linear correlations of forecast S_c4 with S_c10 were 0.95 for both summers (1981-82). The two predicted the same category almost 50% of the time, were within one category of each other 92%, and within two 100% of the time. Thus, the S_c10 will be retired in favor of the areal S_c4 for 1983.

Table 10. HAIL/NO HAIL forecast verification, 1982.

OBSERVED	FORECAST: NO HAIL	FORECAST: HAIL
NO HAIL	27	13
HAIL	8	31

Correct hail days forecast: 31 days = 79.5%
Correct hail-no hail stratification: 58 days = 73.4%

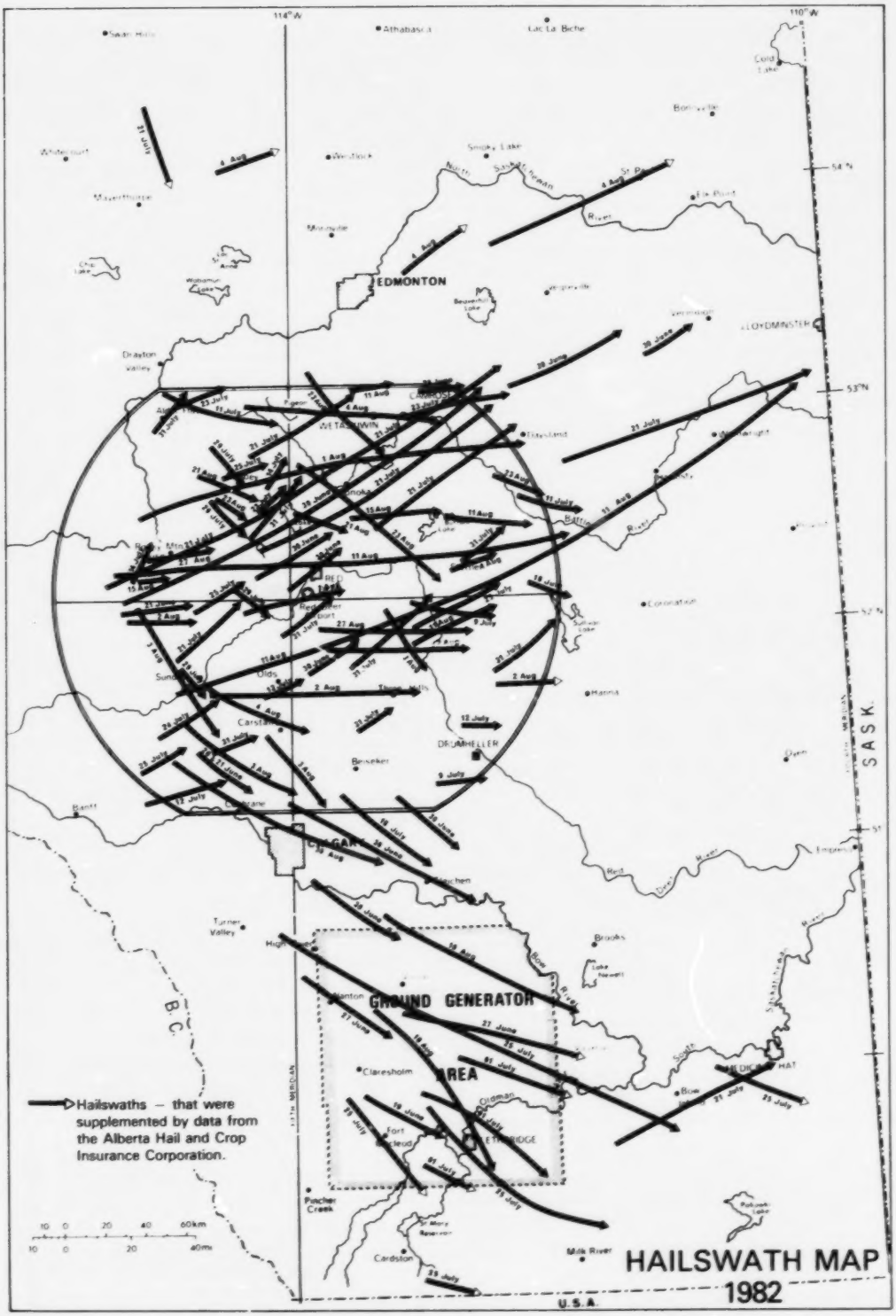


Figure 9. Hailstorm tracks during 1982. Hailswaths are determined by using two or more reports of pea or larger size hail. The arrows indicate approximate center line and direction of the storm.

HAILFALL ACTIVITY

The 1982 hail season was noted not so much for the number of hailstorms but for severity. Walnut or larger hail was recorded (2 or more reports) on 13 days and, of these, 5 had golfball or larger hail reported.

A major storm of the year occurred on 21 July; the 395 hail reports accounted for almost ⅔ of the month's total for the northern area. Hail up to 8 cm was reported, with the hailswath estimated to be as wide as 50 km in some areas (Figure 9).

Major storm days (100 or more hail reports) occurred on five days in the northern project area and on 3 days in the southern project area. The storms in the northern area on 30 June, 21 July and 1, 11 and 23 August accounted for 1166 hail reports or 73% of the total reports for that area. The 392 hail reports from the storms on 2, 3 and 11 August accounted for 47% of the total reports for the southern area.

Hail occurred on 49 days (hail day: one or more hail reports) in the project area, 4% above the 26 year (1957-1982) average for the period 1 June through 30 September; 2431 hail reports were received, 5% below average. In the northern area, hail was reported on 38 days, 3% below average. The 1597 hail reports received were 11% above average. In the southern area hail was reported on 40 days, 5% above average with 834 hail reports received, 32% below average. Appendix 10 summarizes hail days and hail reports on a monthly basis.

Hail reporting cards combined with a project brochure were mailed (via Householder Mailings) to 70,649 farms in the Province; 17,409 of these were inside the project area. Additional cards were sent to those who reported hail. During the reporting period, 1 June to 30 September, 615 hail reports were received from the farmers throughout the province.

The hail card format was extensively modified in an attempt to increase the response rate by making the card easier to fill out. The new format is shown in Appendix 10.

Telephone surveys were conducted on 44 days between 20 June and 10 September, resulting in 2022 hail reports from inside the project area. Surveys of storms that extended outside the project area accounted for 71 hail reports. Dense surveys were conducted on 30 June and 11, 21 and 25 July.

PUBLIC RELATIONS

The Alberta Hail Project represented the Alberta Research Council's single greatest concentration of public relations activity during 1982.

The first major event of the year was the visit of four scientists from the Academy of Sciences of the Peoples Republic of China on 7 through 9 June. The Alberta Research Council coordinated hospitality and entertainment in Edmonton and Red Deer and presented the visitors with a souvenir photo album of their visit. During their visit to the Atmospheric Sciences Department in Edmonton, French and English television crews from CBC and ITV attended the Monday afternoon tour and included stories in their evening newscasts. A Red Deer Advocate reporter wrote a story on the Red Deer tour the following day.

A second major event, on 24 June, was the news conferences to announce the research aircraft. In the morning, ARC and INTERA Environmental Consultants Ltd. representatives made an announcement to all major news media representatives in the INTERA hangars at the Calgary International Airport. In the afternoon, a second news conference was held at the Administration Building of the Alberta Research Council in Red Deer while the new aircraft was on display in the INTERA hangars at the Red Deer Industrial Airport. The news conferences received wide coverage in both cities. A follow-up story appeared in the Alberta Report magazine.

A third major event of 1982 was the tour of the Alberta Hail Project on 13 August. Guests included local businessmen, farmers, government officials, MLAs and an MP, CFB Penhold officers, airport officials, Alberta Agriculture and Agriculture Canada personnel, Hail and Crop Insurance Corporation general manager, members of the Research and Science Policy Committee and members of the Advisory Committee on Weather Modification. A CKRD television crew also attended. The tour was held to familiarize the guests with the significance and the benefits of the project and to show them the facilities and equipment used. Some members of the Alberta Research Council's Board of Directors and representatives of INTERA also attended as hosts.

In addition, the project hosted delegates to the Red Polled Cattlemen's International Convention. Delegates from Canada, England, Scotland, United States, Australia and New Zealand were given a briefing on the project followed by a tour of the project facilities and seeding aircraft.

Also noteworthy was the meeting of the ARC Board of Directors held in Penhold on 25 June. After the meeting, the members attended a social luncheon at the CFB Penhold Officers' Mess followed by a tour of the project.

As a result of media relations activites in the fall of 1981, a feature on the Alberta Hail Project and the new research aircraft was arranged with the science columnist for the Edmonton Journal. The feature appeared in early July. A spin-off feature as part of a larger story is scheduled to appear in a future issue of Equinox magazine, a high quality product of the publishers of Harrowsmith magazine.

Six news releases were distributed during the summer resulting in various news stories in newspapers in the project area. Shortly after the largest storm of the summer, most news media in the area were phoned and advised that scientists had unique observations of the storm that might be of interest to the public. This telephone compaign generated considerable interest.

DISCUSSION

In conjunction with Alberta Agriculture, the Research Council is now in the third year of a five-year program designed to assess the feasibility of weather modification. At the present time, most of the weather modification effort is directed towards suppressing hail. It is estimated that damage to crops due to hailstorms alone amounts to $100 million annually. However, losses due to floods and/or droughts account for additional tens of millions of dollars. For this reason, the Alberta Research Council's weather modification efforts have been broadened to include rainfall management (suppression and enhancement where required) and snow augmentation.

The INTERA/ARC Research Aircraft Facility, played a key role in weather modification feasibility experiments in 1982. Foremost among the research missions were three hailstorm seeding experiments carried out on the storms of 30 June, 21 July and 1 August. The storm of 21 July was the largest of the year. In these experiments, regions where hail embryos are thought to originate were seeded and the precipitation development was subsequently documented by repeated penetrations of the seeded area by the research aircraft. Instrumentation onboard the aircraft allows documentation of ice particles created by the seeding, their growth and motion. The data collected during these experiments will be analyzed in the coming months.

Hailstorms and their modification are very complex problems. A considerably simpler problem is represented by cumulus clouds and their modification for rain enhancement or suppression. Seeding experiments carried out in 1978 and 1979 on cumulus clouds strongly suggested that rain can sometimes be initiated by cloud seeding in clouds that would not naturally produce rain. These experiments involve numerous penetrations (after seeding) by suitably instrumented research aircraft to document the initiation, growth and motion of ice crystals, and therefore precipitation particles produced by seeding. In these clouds, rain development is further documented by radar. As a result of the experiments of 1978 and 1979, it was found that seeded clouds (which were not expected to produce rain naturally) produced an initial radar echo that had the shape of a tube, oriented parallel to the seeding track. In 1982, a further eight clouds were seeded for rain initiation. Of the eight clouds seeded, three produced the distinctive tube-like initial radar echo. The other five clouds did not produce a radar echo and did not produce any rain. (Although it is expected that seeding hailstorms for hail suppression would also produce this distinctive initial echo, the seeded areas merge rapidly with the main storm so that an echo due to seeding is masked by the echo of the main storm.)

In carrying out the hail and rain seeding experiments, some problems were encountered in determining whether or not a particular cloud met the required criteria for experimentation and in finding the test cloud for subsequent penetrations, because of the lack of real-time data available onboard the aircraft. These problems have now been overcome by the implementation, in August, of a software based data system on the INTERA/ARC Research Aircraft. The new computer-directed system incorporates three (LSI-11/23) microprocessors, a CAMAC modular interface, a Cipher microstreamer tape drive, and a Winchester/Floppy disk storage unit. The system is very versatile and can be operated in a variety of modes by simply entering a new program into the memories of the computers. Various airborne data acquistion modes, self-check data quality assurance modes, and data processing modes are possible.

The software based system has expanded our capabilities in data acquisition, recording and display. The primary consideration for the system is that the scientist onboard is able to obtain real-time data via video monitors in a fast and convenient manner allowing diagnosis of the science of the experiment while it is being performed.

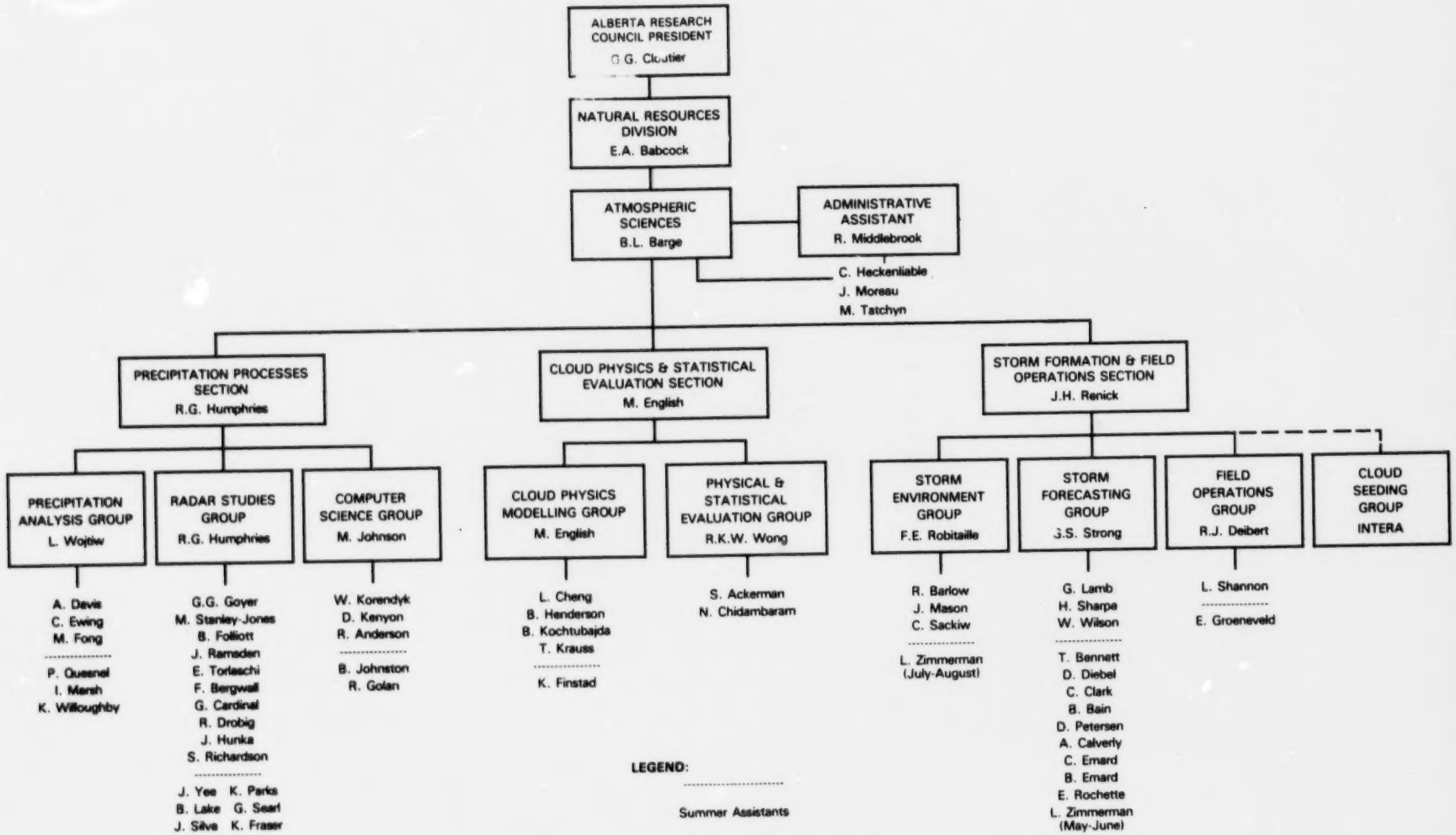
Whereas experimentation with the research aircraft allows us to connect cloud seeding with changes in

hailfall or rainfall, assessment of the effectiveness of weather modification attempts requires accurate measurements of hailfall and rainfall at the ground. In the past year, considerable advances towards accurate precipitation measurements have been made. Experience to date suggests that the most desirable hail/rain measurements for the purposes of weather modification assessment are the number concentration and size of the precipitation particles. Time-resolved measurements of hail and rain size and concentration at the ground, obtained by storm chase vehicles and crews, have been used to interpret radar measurements. Using information from these ground measurements and polarization diversity radar, it has been possible to devise a scheme to separate the rain component from the hail component in radar observations of precipitation. Furthermore, it is expected that the actual concentration and size of the hailstones and raindrops producing the radar signal can also be determined. (Incidentally, the ground measurements suggest that storms have a similar propensity to produce hail. That is, if environmental conditions are such as to produce only small hail, the storms compensate by producing many more hailstones. This, in turn, suggests that if many more hailstones can be produced by cloud seeding, the resultant size of the hailstones will be smaller.)

With a view to diversifying activity within the department somewhat, a project to investigate the effects of sulfur emissions on precipitation processes in Alberta was initiated.

APPENDICES 1 to 11

APPENDIX 1. Portion of the Alberta Research Council organization chart, and the Atmospheric Sciences Program organization chart



ATMOSPHERIC SCIENCES PROGRAM		PRECIPATION PROCESSES SECTION			CLOUD PHYSICS & STATISTICAL EVALUATION SECTION		STORM FORMATION & FIELD OPERATIONS SECTION		
Projects	Sub-Projects	Precipitation Analysis	Radar Studies	Computer Science	Cloud Physics Modelling	Physical/Statistical Evaluation	Storm Environment	Storm Forecast	Field Operations
WEATHER MODIFICATION	HAIL/RAIN	X	X	X	X	X		X	X
	CLOUD SEEDING	X	X	X	X			X	X
	GROUND GENERATOR			X	X	X	X	X	X
	SULFUR-PRECIPITATION	X			X	X		X	X
	SNOW	X		X	X		X	X	X
APPLICATIONS	ERT/RAYTHEON			X					
	FLOW FORECASTING	X	X	X					
	RAIN SAT.		X	X				X	

APPENDIX 2. Atmospheric Sciences Program matrix structure. Group elements within the sections contribute resources to projects and subprojects. Project applications are various spin-offs from the Weather Modification Project, and were not actively involved in the 1982 field program (see Atmospheric Sciences Department 1982 Annual Report).

APPENDIX 3. INTERA/ARC Research Aircraft flights

Date 1982	Time	Experiment	Hrs.
June 1	0936 - 1057	Data Monitoring	1.3
June 3	0923 - 1048	Data Monitoring	1.4
June 3	1234 - 1330	Data Monitoring	0.9
June 4	1421 - 1546	Data Monitoring	0.3
		Thunderstorm	1.1
June 7	1154 - 1223	Data Monitoring	0.5
June 7	1445 - 1539	Data Monitoring	0.4
		Thunderstorm	0.5
June 8	1449 - 1611	Data Monitoring	1.0
		Thunderstorm	0.4
June 11	0827 - 0908	Data Monitoring	0.7
June 13	1238 - 1404	Rain	1.4
June 15	1515 - 1653	Rain	1.6
June 16	1423 - 1643	Rain	2.3
June 18	1606 - 1633	Data Monitoring	0.4
June 20	1030 - 1054	Ground Generator	0.4
	1655 - 1824	Rain	1.5
June 21	1603 - 1743	Ground Generator	1.7
June 24	1728 - 1850	Ground Generator	1.4
June 25	1533 - 1651	Rain	1.3
June 26	1734 - 1954	Ground Generator	2.3
June 27	1342 - 1642	Ground Generator	3.0
June 29	1420 - 1600	Ground Generator	1.7
June 30	1430 - 1832	Hail	4.0
June 30	1931 - 2108	Ground Generator	1.6
July 1	1154 - 1257	Scale Interaction	1.0
July 2	1649 - 1709	Ground Generator	0.3
July 3	1029 - 1052	Ground Generator	0.4
July 3	1647 - 1827	Ground Generator	1.7
July 4	1430 - 1754	Ground Generator	3.4
July 6	1722 - 1912	Data Monitoring	1.0
		Thunderstorm	0.8
July 7	1718 - 1807	Data Monitoring	0.8
July 8	1800 - 1823	Data Monitoring	0.6
July 9	1616 - 1707	Ground Generator	0.8
July 9	1901 - 1926	Ground Generator	0.4
July 10	1623 - 1847	Thunderstorm	2.6
July 11	1615 - 1935	Thunderstorm	3.3
July 12	1639 - 1936	Ground Generator	3.0
July 13	1313 - 1501	Sulfur	1.8
July 17	1609 - 1847	Rain	2.6
July 18	1515 - 1650	Rain	1.6
July 21	1656 - 1932	Ground Generator	2.6
July 21	2025 - 2202	Hail	1.6
July 24	1708 - 1908	Rain	2.0
July 25	1516 - 1820	Ground Generator	3.1
July 27	1027 - 1208	Scale Interaction	1.7
July 27	1652 - 1817	Thunderstorm	1.4
July 28	1706 - 1944	Ground Generator	2.6
July 30	1336 - 1659	Data Monitoring	3.4
July 31	1419 - 1627	Ground Generator	2.1
August 1	1458 - 1627	Hail	1.5
August 2	0710 - 0930	Ground Generator	2.3
August 2	1632 - 1920	Ground Generator	2.8
August 3	1059 - 1418	Ground Generator	3.3
August 3	1630 - 1755	Ground Generator	1.4
August 3	1828 - 2014	Ground Generator	1.8
August 23	1806 - 1945	Data Monitoring	1.6
August 28	1810 - 1912	Data Monitoring	1.0
August 30	1936 - 2016	Data Monitoring	0.7
September 1	1813 - 1930	Data Monitoring	1.3
September 3	1715 - 1824	Data Monitoring	1.2
September 5	1513 - 1610	Sulfur	0.9
September 6	1228 - 1351	Sulfur	1.4
September 7	1548 - 1800	Sulfur	2.2
September 8	0954 - 1147	Sulfur	1.9
September 9	1356 - 1520	Sulfur	1.4
September 9	1650 - 1736	Rain	0.8
September 10	1332 - 1506	Sulfur	1.6
September 11	1130 - 1339	Sulfur	2.1
September 12	1029 - 1142	Sulfur	1.2
		TOTAL	112.1

APPENDIX 3. (continued)

Results of controlled rain seeding flights

Date of Experiment	No. of Clouds Seeded	Treatment Type	Problems	No. of Echoes Produced
June 13	0		Seeding aircraft's transponder not functioning.	–
June 15	1	AgI		1
June 16	0		Seeding aircraft's transponder not functioning.	–
June 20	2	AgI	Transponder fluctuations. Belly pitot sensor not functioning. CRT not functioning. Seeding aircraft's transponder not functioning.	1
June 25	0			–
July 17	4	AgI, placebo, CO_2	2-DC probe not functioning. Belly pitot sensor malfunctions during the flight	1
July 18	1	placebo		0
July 25	0			–
Sept. 9	0			–
TOTALS	8			3

APPENDIX 4. Airsonde releases - July and August 1982

	CIS #1		CIS #2		CIS #3	
DATE	SITE #	RELEASES	SITE #	RELEASES	SITE #	RELEASES
July 1	214	4	223	3	206	4
July 8	221	4	202	3	223	3
July 9	QF	1			QF	2
July 10					QF	2
July 11	QF	1				
July 12	QF	2				
July 12	211	3	QF	2	213	4
July 13	QF	2				
July 14	225	3	202	4	211	6
July 14	224	1				
July 19	228	2	208	2	226	2
July 21	229	1	202	4	QF	2
July 21	230	1			203	4
July 23					QF	2
July 25	QF	2			QF	2
July 26	228	3	227	3	226	3
July 27	222	5	203	6	223	6
July 29	224	6	213	3	RM	4
July 29			202	1		
August 24	301	1	302	3	303	2

APPENDIX 4. (continued) Surveyed upper-air sites

SITE #	LAND LOCATION	ELEVATION (m)
201	SE16 34 27 4	969
202	NE32 33 01 5	1009
203	SE22 38 03 5	937
204	SE17 39 27 4	888
205	NE17 40 26 4	861
206	SW02 43 25 4	856
207	SW34 41 21 4	792
208	NW11 39 20 4	813
209	SE10 37 23 4	882
210	NE22 35 25 4	964
211	NE21 31 24 4	857
212	SW31 28 25 4	947
213	SW30 29 01 5	1082
214	SE16 37 07 5	1078
215	SW34 43 02 5	926
216	NW15 46 20 4	741
217	SE14 33 21 4	853
218	SW26 26 01 5	1116
219	NE01 41 02 5	945

SITE #	LAND LOCATION	ELEVATION (m)
220	SE18 46 24 4	769
221	SE27 33 07 5	1197
222	SW15 39 07 5	996
223	SE34 35 24 4	948
224	SW26 33 07 5	1258
225	NE32 28 05 5	1386
226	SW33 37 26 4	972
227	NW15 36 27 4	941
228	NE36 36 26 4	986
229	SE36 39 03 5	975(E)
230	SE36 42 26 4	814
301	SW27 34 11 5	1506
302	SE08 35 09 5	1276
303	NW16 33 10 5	1468
304	SE07 34 10 5	2121
305	SE30 33 10 5	1974
QF	SW13 37 28 4	900
YC	NW36 24 02 5	1114
RM	SE14 40 07 5	988

APPENDIX 4. (continued) CIS support soundings

DATE	SITE	RELEASE TIMES (UTC)	PURPOSE
July 1	214	1720, 1900, 2115, 2200	CIS
	223	1939, 2155, 2251	CIS
	206	1718, 1904, 2106, 2302	CIS
	QF U/A	2105	CIS
July 8	221	1730, 1805, 1920, 2130	CIS
	202	1742, 1914, 2104	CIS
	223	1721, 1900, 2102	CIS
July 9	QF	1625, 2057, 2225	I
July 10	QF	1605, 1750	I
July 11	QF	1615	I
July 12	QF	1530, 1700	CIS
	QF	2008, 2244	CIS
	213	1841, 2105, 2202, 2312	CIS
	211	2200, 2300	CIS
July 13	211	0030	CIS
	QF	1530, 1726	CIS
July 14	225	1737, 1838, 1948	CIS
	224	2301	CIS
	202	1922, 2101, 2204, 2306	CIS
	211	1615, 1900, 2100, 2120, 2320, 2335	CIS
	QF U/A	1515, 1730	CIS
	YC U/A	1515, 1720	CIS
July 19	228	1833, 2024	F
	227	1831, 2016	F
	226	1830, 2015	F
July 21	QF	1836, 1945, 2353	CIS
	202	2305, 2337	CIS
	QF U/A	2015	CIS
	YC U/A	2356	CIS
July 22	202	0017, 0132	CIS
	QF	0012, 0040, 0230	CIS
	229	0000	CIS
	230	0230	CIS
	QF U/A	0022	CIS
July 23	QF	1732, 2005	I
July 25	QF	1542, 1538, 2002, 2004	F
July 26	228	1728, 2004, 2115	F
	227	1728, 2003, 2117	F
	226	1728, 2000, 2115	F
	QF U/A	2000	I
July 27	222	1755, 1935, 2100, 2238, 2400	CIS
	203	1741, 1925, 2100, 2226, 2336, 2359	CIS
	223	1721, 1812, 1933, 2106, 2135	CIS
July 28	223	0003	CIS
July 29	224	1858, 1959, 2147, 2226, 2259	CIS
	213	1916, 2026, 2153	CIS
	RM	1900, 2015, 2145, 2310	CIS
	QF U/A	1915	CIS
	YC U/A	2010	CIS
July 30	224	0019	CIS
	202	0035	CIS
August 24	301	2106	LF
	302	2107, 2134, 2241	LF
	303	2030, 2230	LF

LF - Limex Frequency Test

APPENDIX 5. I.P. Krick ground generator sites visited

Sequence Number	Site Number	Date Visited 1982	Time Visited	Site Operating	Was It Asked To Operate?	Fuel Rate g/hr
1	45	July 8	1524	No	No	30
2	43	July 8	1714	Yes	Yes	30
3	43	July 8	1714	Yes	Yes	2
4	56	July 8	1851	No	No	30
5	34	July 14	1319	Yes	Yes	15
6	33	July 14	1409	Yes	Yes	15
7	32	July 14	1459	Yes	Yes	30
8	64	July 14	1555	Yes	Yes	2
9	22	July 14	1809	No	Yes	30
10	11	July 15	1319	No	No	30
11	1	July 15	1431	No	No	30
12	7	July 15	1624	No	No	15
13	16	July 15	1701	No	No	15
14	20	July 16	1001	No	No	15
15	27	July 16	1110	No	No	15
16	29	July 16	1213	No	No	15
17	38	July 16	1332	No	No	15
18	40	July 16	1424	No	No	30
19	41	July 16	1448	No	No	15
20	1	July 21	1611	Yes	Yes	30
21	11	July 21	1722	No	Yes	30
22	13	July 21	1815	Yes	Yes	30
23	14	July 22	1204	No	No	15
24	21	July 22	1248	No	No	15
25	26	July 22	1402	No	No	30
26	30	July 22	1430	No	No	15
27	42	July 22	1538	No	No	30
28	56	August 2	1640	Yes	Yes	30
29	44	August 2	1740	Yes	Yes	15
30	45	August 2	1820	Yes	Yes	30
31	34	August 3	1135	Yes	Yes	15
32	33	August 3	1205	Yes	Yes	15
33	31	August 3	1255	Yes	Yes	15
34	35	August 3	1345	Yes	Yes	30
35	24	August 3	1530	Yes	Yes	30
36	25	August 3	1600	Yes	Yes	30
37	28	August 3	1655	No	Yes	15
38	37	August 3	1735	Yes	Yes	30
39	36	August 3	1805	Yes	Yes	15
40	52	August 3	1915	Yes	Yes	2
41	52	August 3	1915	No	No	30
42	23	August 4	1555	No	No	30
43	12	August 4	1640	No	No	15
44	67	August 4	1725	No	No	15
45	10	August 4	1850	No	No	15
46	9	August 4	1828	No	No	15
47	15	August 5	1055	No	No	30
48	18	August 5	1155	No	No	30
49	25	August 5	1305	No	No	30
50	36	August 5	1440	No	No	15

APPENDIX 5. (continued) Coke fuel samples collected for chemical analysis

Sample Number	Date Taken 1982	Time Taken	Fuel Rate	Sample Weight	ARC Personnel Present	I.P. Krick Personnel Present
1	July 8	1524	30 gm/hr	90 gms	H. Chatenay	–
2	July 8	1714	30 gm/hr	100 gms	H. Chatenay	–
3	July 8	1851	30 gm/hr	70 gms	H. Chatenay	–
4	July 14	1319	15 gm/hr	140 gms	H. Chatenay	R. Bishop
5	July 14	1409	15 gm/hr	170 gms	H. Chatenay	R. Bishop
6	July 14	1459	30 gm/hr	110 gms	H. Chatenay	R. Bishop
7	July 14	1809	30 gm/hr	160 gms	H. Chatenay	R. Bishop
8	July 15	1319	30 gm/hr	100 gms	H. Chatenay	R. Bishop
9	July 15	1431	15 gm/hr	120 gms	H. Chatenay	R. Bishop
10	July 15	1624	15 gm/hr	160 gms	H. Chatenay	R. Bishop
11	July 15	1700	15 gm/hr	110 gms	H. Chatenay	R. Bishop
12	July 16	1001	15 gm/hr	150 gms	H. Chatenay	R. Bishop
13	July 16	1110	15 gm/hr	170 gms	H. Chatenay	R. Bishop
14	July 16	1213	15 gm/hr	150 gms	H. Chatenay	R. Bishop
15	July 16	1332	15 gm/hr	120 gms	H. Chatenay	R. Bishop
16	July 16	1424	30 gm/hr	160 gms	H. Chatenay	R. Bishop
17	July 16	1448	15 gm/hr	210 gms	H. Chatenay	R. Bishop
18	July 21	1611	30 gm/hr	180 gms	H. Chatenay	R. Bishop
19	July 21	1722	30 gm/hr	170 gms	H. Chatenay	R. Bishop
20	July 21	1815	30 gm/hr	180 gms	H. Chatenay	R. Bishop
21	July 22	1204	15 gm/hr	190 gms	H. Chatenay	R. Bishop
22	July 22	1248	15 gm/hr	200 gms	H. Chatenay	R. Bishop
23	July 22	1402	30 gm/hr	200 gms	H. Chatenay	R. Bishop
24	July 22	1430	15 gm/hr	210 gms	H. Chatenay	R. Bishop
25	July 22	1538	30 gm/hr	220 gms	H. Chatenay	R. Bishop
26	August 2	1640	30 gm/hr	280 gms	S. Tekelenburg	Ed Wentworth
27	August 2	1740	15 gm/hr	240 gms	S. Tekelenburg	Ed Wentworth
28	August 2	1820	30 gm/hr	280 gms	S. Tekelenburg	Ed Wentworth
29	August 3	1135	15 gm/hr	210 gms	S. Tekelenburg	R. Bishop
30	August 3	1205	15 gm/hr	220 gms	S. Tekelenburg	R. Bishop
31	August 3	1255	15 gm/hr	220 gms	S. Tekelenburg	R. Bishop
32	August 3	1345	30 gm/hr	260 gms	S. Tekelenburg	R. Bishop
33	August 3	1530	30 gm/hr	240 gms	S. Tekelenburg	R. Bishop
34	August 3	1600	30 gm/hr	250 gms	S. Tekelenburg	R. Bishop
35	August 3	1655	15 gm/hr	230 gms	S. Tekelenburg	R. Bishop
36	August 3	1735	30 gm/hr	240 gms	S. Tekelenburg	R. Bishop
37	August 3	1805	15 gm/hr	210 gms	S. Tekelenburg	R. Bishop
38	August 4	1555	30 gm/hr	260 gms	S. Tekelenburg	R. Bishop
39	August 4	1640	15 gm/hr	250 gms	S. Tekelenburg	R. Bishop
40	August 4	1725	15 gm/hr	240 gms	S. Tekelenburg	R. Bishop
41	August 4	1850	15 gm/hr	210 gms	S. Tekelenburg	R. Bishop
42	August 4	1828	15 gm/hr	210 gms	S. Tekelenburg	R. Bishop
43	August 5	1055	30 gm/hr	210 gms	S. Tekelenburg	R. Bishop
44	August 5	1155	30 gm/hr	250 gms	S. Tekelenburg	R. Bishop

APPENDIX 6. Seeding aircraft flare systems

	Registration	Type	Hailstop #	Base Flare System	Top Flare System
	C-FHRA	PAZT	1	Acetone (End Burners)*	Large Top
	C-GRSJ	C310	2	End Burners (Acetone)	Large Top
	C-GRKM	C310	3	Acetone (End Burners)	Pencil
	C-GRST	C340	4	End Burners	Pencil
Backup	C-GBLB	C310	5	End Burners	Large Top
Aircraft	C-GELL	C411	6	End Burners	Pencil (Large Top)

*Systems in brackets ( ) denote alternate aircraft capability.

APPENDIX 6. (continued) Summary of missions flown by seeding aircraft

Date 1982	PATROL	SEEDING	TEST	ARC SUPPORT	RESEARCH	FERRY	TRAINING	TOTAL
1 - 14 June					3 **4.6**			3 **4.6**
15 - 19 June			2 **1.3**		2 **3.8**	7 **3.6**	9 **6.3**	20 **15**
20 June 31 August	75 **365.6**	87	17 **9.3**	6 **7.4**	10 **20.9**	37 **32.2**	3 **2**	235 **437.4**
1 - 12 September					1 **0.9**			1 **0.9**
1 June - 12 September TOTAL	75 **365.6**	87	19 **10.6**	6 **7.4**	16 **30.2**	44 **35.8**	12 **8.3**	259 **457.9**

NOTE: The upper number is the number of flights, the lower number is the flight hours (air time) of those flights.

APPENDIX 6. (continued) INTERA project personnel, 1982 AHP

CHIEF OFFICER:		B.L. Bullock
CONTRACT SUPERVISOR:		K.L. Grandia
RADAR CONTROLLERS:		G. Toth M. Bullock M. Oleskiw
CHIEF PILOT:		P. Lens
FLARE TECHNICIAN:		W. Cozens
AIRCREWS:	P. Lens	M. Lawrysyn
	P. Gibson	B. Carter
	S. Holliday	R. Gantner
	P. Grimsey	S. Grisbrook
	L. Baker	G. Rowland
RESEARCH AIRCRAFT:		A. Lisonbee E. Leavitt D. Healey T. Spoering A. Stuart

APPENDIX 7. Daily radar/computer tape logs

Dates and times for which C-band data was logged

03-JUN-82	15:43	16:29
04-JUN-82	11:10	13:19
	13:30	15:21
	15:23	16:25
07-JUN-82	15:13	17:01
08-JUN-82	13:17	14:47
	15:11	24:00
09-JUN-82	00:00	05:26
	11:51	21:04
10-JUN-82	00:59	06:07
	07:00	11:36
	13:01	14:31
	20:11	24:00
11-JUN-82	00:00	01:11
	12:43	17:58
	21:04	23:02
12-JUN-82	03:12	05:13
	07:27	11:31
	18:56	23:03
13-JUN-82	08:11	10:32
	11:31	14:05
	15:24	18:31
	19:58	24:00
14-JUN-82	00:00	01:58
	03:16	24:00
15-JUN-82	00:00	09:18
	11:41	24:00
16-JUN-82	00:00	08:17
	11:02	11:17
	11:50	17:13
	19:39	24:00
17-JUN-82	00:00	09:53
18-JUN-82	02:11	09:17
	17:18	21:14
19-JUN-82	07:33	24:00
20-JUN-82	00:00	07:30
	11:51	24:00
21-JUN-82	00:00	04:26
	09:27	24:00
22-JUN-82	00:00	06:44
	08:25	15:36
	15:42	24:00
23-JUN-82	00:00	05:49
	12:47	24:00
24-JUN-82	00:00	09:56
	11:06	14:12
	14:16	19:19
25-JUN-82	13:24	19:33
	21:40	24:00
26-JUN-82	00:00	06:39
	11:32	24:00
27-JUN-82	00:00	19:55
	20:08	24:00
28-JUN-82	00:00	20:16
29-JUN-82	08:01	15:01
	17:06	24:00
30-JUN-82	00:00	03:45
	04:14	09:20
	11:47	24:00
01-JUL-82	00:00	01:20
	12:25	24:00
02-JUL-82	00:00	06:57
	07:06	10:39
	10:40	12:27
	12:28	16:42
	16:51	21:00
	21:18	24:00
03-JUL-82	00:00	12:45
	12:53	24:00
04-JUL-82	00:00	02:57
	03:00	13:28
	13:33	18:58
	18:59	24:00
05-JUL-82	00:00	11:53
	17:08	17:47
06-JUL-82	00:30	09:50
	12:19	24:00
07-JUL-82	00:00	03:58
	07:52	08:53
	11:47	24:00
08-JUL-82	00:00	08:43
	09:49	19:04
10-JUL-82	05:07	16:49
11-JUL-82	00:25	07:04
	08:05	15:22
	22:57	24:00
12-JUL-82	00:00	11:52
	12:19	13:25
	17:15	17:28
	17:30	19:05
	19:14	24:00
13-JUL-82	00:00	04:09
	16:32	24:00
14-JUL-82	00:00	01:14
	07:57	08:27
	09:14	14:32
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	18:29	21:10
	22:35	24:00
15-JUL-82	00:00	00:55
	01:15	09:33
	13:35	23:59
16-JUL-82	00:02	04:57
	07:32	08:23
17-JUL-82	00:15	03:28
	12:49	13:03
	13:04	15:01
	22:12	24:00
18-JUL-82	00:00	03:12
	04:15	11:45
	23:55	24:00
19-JUL-82	00:00	01:48
	03:45	18:18
	20:29	24:00
20-JUL-82	00:00	22:58
	23:17	24:00
21-JUL-82	00:00	01:28
	02:20	11:16
	13:42	14:22
22-JUL-82	01:53	10:49
	15:32	19:20
23-JUL-82	15:22	22:24
24-JUL-82	22:59	24:00
25-JUL-82	00:00	12:05
27-JUL-82	10:49	11:37
	14:43	15:16
	22:53	24:00
28-JUL-82	00:00	01:20
	16:55	20:52
29-JUL-82	02:15	06:27
	12:19	13:27
	15:28	21:20
	21:52	24:00
30-JUL-82	00:00	05:10
	20:02	22:59
31-JUL-82	02:01	12:03
	22:05	24:00

APPENDIX 7. (continued)

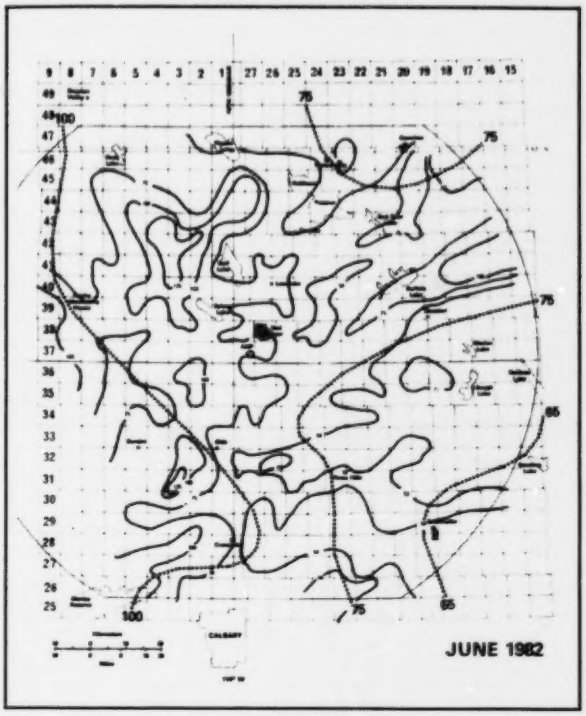
Dates and times for which C-band data was logged (continued)

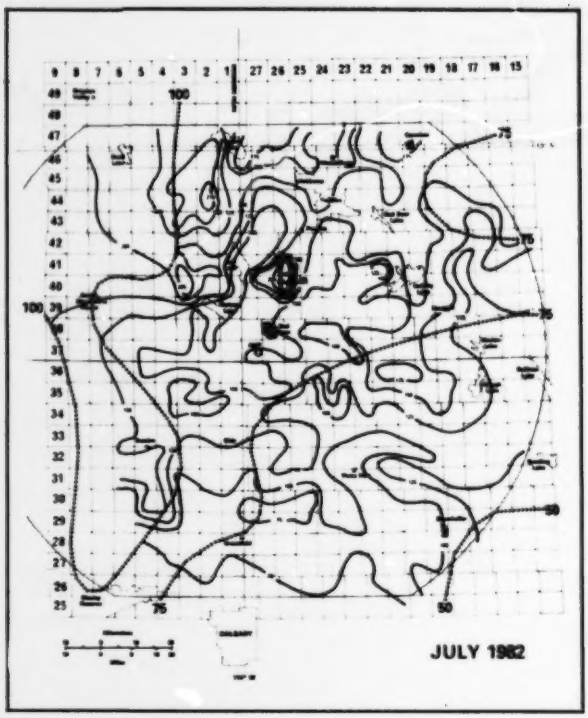
01-AUG-82	00:00	02:18
	03:03	03:30
	17:30	24:00
02-AUG-82	00:00	09:31
	13:16	22:00
03-AUG-82	13:17	19:15
	19:17	24:00
04-AUG-82	00:00	02:23
	13:34	21:12
08-AUG-82	11:21	12:13
	13:23	14:32
09-AUG-82	13:33	20:35
10-AUG-82	20:16	24:00
11-AUG-82	00:00	07:57
	11:44	14:33
	14:42	16:58
	17:00	17:54
	18:05	22:25
12-AUG-82	02:59	09:39
	09:45	11:37
	13:33	22:13
13-AUG-82	12:09	13:26
	16:26	20:12
14-AUG-82	02:59	08:40
	08:51	10:04
	10:15	19:20
	21:24	24:00
15-AUG-82	00:00	04:11
	13:16	15:36
	15:45	15:55
	16:02	16:58
	21:11	24:00
16-AUG-82	00:00	02:04
	17:39	24:00
17-AUG-82	00:00	02:52
	18:21	19:01
	21:29	24:00
18-AUG-82	00:00	01:32
	02:02	10:42
	18:25	19:33
	23:31	24:00
19-AUG-82	00:00	10:47
20-AUG-82	07:47	24:00
21-AUG-82	00:00	01:41
	12:21	19:23
	19:38	21:24
	21:38	24:00
22-AUG-82	00:00	08:57
	19:02	20:30
23-AUG-82	07:00	21:05
24-AUG-82	14:42	21:15
25-AUG-82	07:33	11:35
	11:55	22:02
26-AUG-82	07:37	11:34
27-AUG-82	14:55	20:56
	21:08	23:12
28-AUG-82	07:45	19:15
29-AUG-82	13:40	20:54
30-AUG-82	07:14	11:52
	13:45	18:31
	18:34	21:38
31-AUG-82	07:23	21:05
01-SEP-82	07:33	09:31
02-SEP-82	09:07	10:26
03-SEP-82	07:24	09:58
	17:11	20:47
04-SEP-82	07:31	13:12
	15:32	15:42
	15:47	21:07
05-SEP-82	07:28	12:24
	17:43	20:17
09-SEP-82	07:36	10:07
	14:54	16:45
10-SEP-82	07:12	13:30
	14:29	15:22
	16:04	20:58

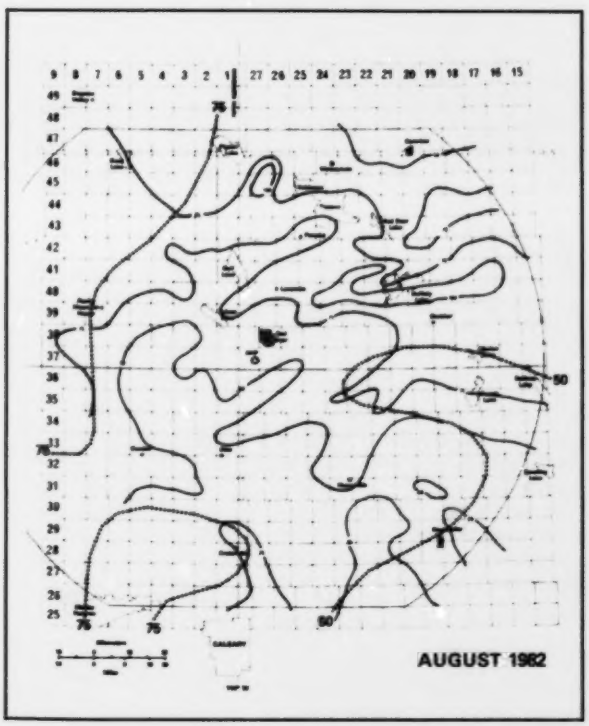
Dates and times for which S-band data was logged

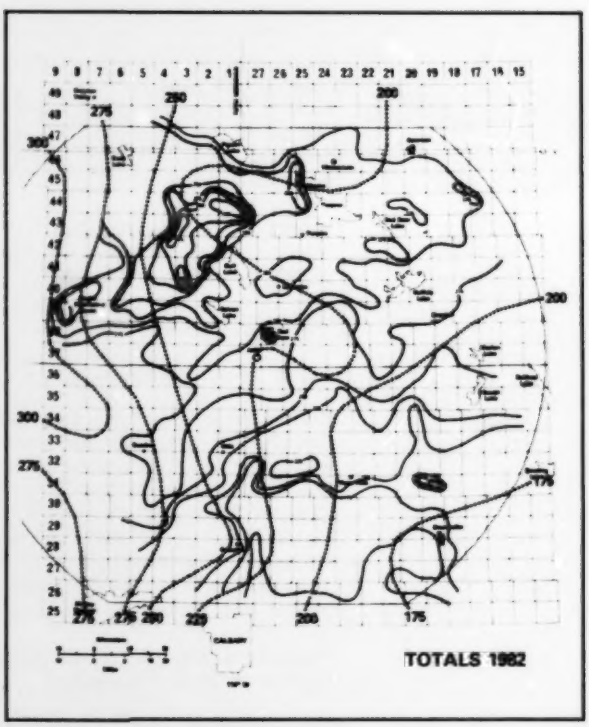
05-JUL-82	18:06	23:46
08-JUL-82	19:05	20:03
09-JUL-82	19:05	20:09
	20:15	20:52
	21:05	21:21
	21:25	23:05
10-JUL-82	16:50	24:00
11-JUL-82	00:00	00:08
	15:33	19:30
	19:34	22:47
12-JUL-82	13:26	16:34
	16:38	17:00
17-JUL-82	15:02	21:44
18-JUL-82	11:46	23:16
19-JUL-82	18:20	20:24
21-JUL-82	14:54	23:00
24-JUL-82	16:32	22:57
25-JUL-82	12:18	18:41
	18:55	22:51
27-JUL-82	15:36	22:48
31-JUL-82	12:05	16:14
	16:22	18:07
	18:27	22:00
01-AUG-82	13:07	17:15
08-AUG-82	11:21	12:13
	12:23	13:18
13-AUG-82	13:31	16:20
14-AUG-82	08:51	09:11
	09:16	09:36
	09:39	10:04
15-AUG-82	17:16	21:07
04-SEP-82	13:21	14:48
	14:51	15:15
	15:32	15:42
09-SEP-82	16:46	20:49

APPENDIX 8. Project rainfall maps









The contour lines are rainfall amounts in mm. The dotted lines are long-term climatological averages.

APPENDIX 9. Daily summary of hailstorms and cloud seeding activities — 20 June to 31 August

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
June 15-19		Test and training	75	4	—
20	4	Moderately intense, high based storms developed in the foothills W and SW of Red Deer in the early afternoon. The storms weakened and died as they moved SE off the foothills. The storm activity ended by about 1800.	210	39	.7 gal
21	6	Weak storms developed just before noon about 60 mi. W QF. Several new storms developed in the early afternoon in the foothills 60 mi. SW QF. These intensified and merged together into one large storm moving SE toward Calgary, finally dissipating in mid-afternoon. Other moderately intense storms developed in the foothills, moved SE but died shortly after.	228	33	—
22	—	Widespread heavy rainshowers throughout the project area.	—	—	—
23	1	Widespread rainshowers in the project area. A few small, weak cells 40 - 60 mi. WSW QF mid to late afternoon moved SE.	—	—	—
24	—	Widespread rainshowers in an easterly upslope flow. No convective cells.	—	—	—
25	1	Small, weak, short-lived convective cells SW foothills during the middle to late afternoon.	—	—	—
26	2	Small, weak cells 50 - 80 mi. W QF in early afternoon. Later, several cells of moderate intensity developed in the foothills from WNW through SW QF and moved ESE dissipating by 1830. Also, some weak cells occurred 30 mi. S QF in late afternoon, and 25 mi. S QF in the early evening.	—	16	—
27	2	Afternoon rainshowers with a few very weak cells in the SW foothills. Cells moved E in the evening and intensified slightly, but dissipated by 2200.	247	—	—
28	—	No significant activity.	—	—	—
29	—	No significant activity.	—	—	—
30	5	Storms began developing about 1300 just S and W of RM. By 1430 one major storm had intensified to near 60 dBZ, tops 40K. This storm tracked ENE over Eckville, Sylvan Lake, Ponoka, and exited the project area SE of Camrose about 2000. A tornado touched down near Dovercourt at about 1500. Smaller, weak to moderate intensity storms developed 30 - 60 mi. S QF between 1700-1800 and moved NE through the SE quadrant of the project area, dissipating by about 2100.	366	17	—
July 1	2	Frequent rainshowers. A few weak cells in the foothills to the SW of QF in the evening.	—	—	—
2	—	Widespread showers. No significant convection.	—	—	—

APPENDIX 9. (continued)

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
July 3	3	Widespread showers. Several weak cells developed just NW and N of Calgary in the early afternoon and moved NE dissipating by 1700.	–	34	.4 gal
4	–	Rainshowers. No significant convection.	–	–	–
5	–	Rainshowers, mostly in the northern area. A few weak cells in the afternoon near Stettler.	–	–	–
6	5	Weak cells in the foothills SW through NW QF near noon, cells moved E off the foothills in a ragged line, most dissipating by 1530, except for two areas of weak to moderate cells, one 60 mi S QF and the other 25 mi. W QF which moved ENE, gradually dissipating between 1700-1800.	–	51	4.0 gal
7	4	Few weak storms near RM and 30 - 40 mi. NW QF middle to late afternoon. Weak storms 60 mi. SW and 60 mi. SSE QF developed near 1800 and formed a weak, NW-SE line of cells which moved NE toward QF, dissipating by 2000 about 20 mi. S QF.	–	23	–
8	2	Scattered weak cells formed in the early afternoon 60 mi. WSW QF, moved SE, dissipating about 1700. After 1730, new cells formed about 60 mi. ENE QF and 45 mi. SSE QF, dissipating by 1900.	–	19	–
July 9	8	No radar until the evening. Mid afternoon storms about 40 mi. NW-N-NE YC were seeded visually, using aircraft radar guidance. About 1900, a cell formed over Pine Lake and intensified and tracked ESE, reaching 64 dBZ near Big Valley, finally dissipating about 2200 65 mi. ESE QF.	546	24	–
10	5	Moderate cells formed 60 mi ESE and E QF in mid afternoon, and moved eastward and out of the project area by about 1730. An isolated, moderately intense storm formed near Carstairs about 2000, moved eastward, dissipating near Three Hills at about 2200.	101	10	–
11	–	A strong, isolated storm developed near Stettler in mid afternoon and tracked eastward out of the project area by 1630. A compact, intense isolated storm which originated just east of Drayton Valley at 1730 moved SE into the project area, dissipating near Pigeon Lake at about 2030 (reflectivities were 70+ dBZ at one point). Another strong, isolated storm formed near Alder Flats at about 1930 and moved ENE, dissipating in the late evening near Pigeon Lake.	–	–	–
12	5	A line of moderately intense storms formed along the foothills between 1300 and 1400. This N-S line moved eastward and slowly weakened, passing S of Penhold as a disorganized shower area about 1800. There were also some isolated moderate cells 70 - 80 mi. SE QF near 1530. After 1800, an E-W band of showers and weak storms extended from near Penhold to 70 mi. W QF.	80	47	4.0 gal
13	–	Weak evening storms N of RM and near Cochrane.	–	–	–
14	7	A line of weak to moderately intense storms began near noon in a line from Big Valley to Drayton Valley. The storms tracked northward. By 1500 a NNW-SSE line of moderate cells had formed about 60 mi. W QF. This line passed just W QF at about 1700, and weakened in the evening NE of Rimbey.	204	–	–

APPENDIX 9. (continued)

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
July 15	–	Rainshowers mostly in western project area.	–	–	–
16	–	No convection.	–	–	–
17	4	Scattered weak cells formed in the western project area in the early afternoon, with one small, isolated, moderately intense cell 45 mi. NNW QF at 1600. Between 1630-1730, a large, moderate intensity storm formed near RM and another near Caroline. Both moved eastward, the former dissipating near Lacombe near 2000 and the latter dissipating just southeast of Red Deer near 2000.	6	–	4.0 gal
18	5	Small, weak storms formed 55 mi. S QF 1300-1400, reaching moderate intensity near 1430 and moving out of the project area by 1530. Otherwise, there were only isolated, weak afternoon cells in the western project area. Near 1700, a weak cell developed 50 mi. ENE QF. It intensified, moved E and then curved SE, exiting the area about 1900.	48	17	–
19	–	No significant convection.	–	–	–
20	–	No significant convection.	–	–	–
21	4	A major storm developed just W RM near 1400, and tracked ENE, leaving a broad swath of large hail and finally moving out of the project area N of Forestburg at about 2130. Another storm developed 60 mi. SW QF at about 1930 and reached moderate intensity as it moved ENE, finally dissipating just W QF about 2230. Other weak to moderate storms reformed in the area 30 - 50 mi. SW QF about 2300 and moved to within about 20 mi. SW QF before dissipating about midnight.	52	40	–
22	1	No significant convection.	–	–	–
23	2	Moderate cells formed about 1600 60 - 80 mi. SW QF, tracked SE to about 10 mi. NE QF by 1930, when they dissipated. Another compact, isolated moderately intense storm formed near Camrose about 1900 and moved SE dissipating just S of Daysland late in the evening.	–	–	–
24	6	Weak storms began to develop 70 mi. SW QF at 1630. They intensified rapidly and formed a NNW-SSE line. The most intense cells were in the southern end of the line, south of Sundre. The line moved slowly eastward, dissipating about 2200 near Carstairs. The northern end of the line moved eastward and dissipated about 30 mi. NW QF near 1900.	344	5	4.3 gal
25	5	Numerous small cells formed between 40 and 90 mi. SW QF by 1100, and throughout the NW quadrant of the project area by 1200. About 1330, an isolated, intense storm developed near Elnora, tracked NE dissipating near Forestburg in the early evening. By 1500, a line of storms developed in the foothills SW QF. A large, moderately intense storm, near RM about 1400, tracked E dissipating near Wetaskiwin about 2000. The foothills line expanded into a large disorganized area of weak cells, moved E and slowly dissipated SE QF in the evening.	33	–	.7 gal

APPENDIX 9. (continued)

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
July 26	–	No convection.	–	–	–
27	3	Weak to moderate late afternoon storms over the foothills W and SW QF. One moderate intensity storm W Caroline tracked SE over Sundre, dissipating near Didsbury about 2000.	–	–	–
28	2	Weak late afternoon storms over the mountains SW QF, remained outside the project area.	–	–	–
29	5	Near 1500, weak storms began forming 60 - 70 mi. W and SW QF. One moderate cell W of Caroline at 1630 moved SE, dissipating S of Carstairs about 2000. About 1830, several storms formed in the NW quadrant of the project area. By 1900, a line of moderate storms extended from RM, to the NE. This line dissipated near QF about 2130.	26	17	1.2 gal
30	–	Weak afternoon storms over the mountains SW QF remained outside the project area.	–	–	–
31	6	Numerous cells formed just after noon 30 - 50 mi. SW QF and 30 - 60 mi. SE QF. They remained weak to moderate in intensity and moved N. The cells SE QF formed an E-W line with moderate to strong cells at its eastern end 60 - 80 mi. from QF by 1400. These cells dissipated by 1630 about 70 mi. ENE QF. About 1530, more storms began to form near Cochrane. By 1600, these storms had developed to moderate to strong intensity in a WNW-ESE line about 50 mi. SW QF. The line tracked NE passing Penhold about 1900 and dissipating by 2100.	–	67	6.5 gal
August 1	5	A line composed of three moderately intense cells developed around 1300 from Crimson Lake to Caroline. By 1600, the line extended from near Ponoka to Sylvan Lake. The cells at the southern end of the line weakened, while those near Ponoka remained strong. The line dissipated around 1800. Small storms 60 mi. SW QF developed about 1830 and moved northward and dissipated by 2000.	527	–	3.3 gal
2	3	A few weak storms formed 30 - 60 mi. W QF at 1500 but dissipated by 1600, when a new strong storm developed 50 mi. ESE QF. This storm moved SE to Sundre and then E to Three Hills by about 2000 when it dissipated. A weak SW-NE line of storms 35 mi. ESE QF at 1930 moved eastward and out of the project area by 2100.	36	27	.8 gal
3	6	By 1500, a line of storms from 60 mi. S QF through 60 mi. SW QF had formed. The line moved eastward, dissipating in the SE quadrant of the project area in the early evening. More cells developed near 1800 50 - 60 mi. W QF. They moved SE and developed to a moderate intensity, finally dissipating S of Sundre about 2200.	–	31	5.6 gal
4	1	Storm activity was confined to the northern project area. About 1430 cells developed in the Eckville and Alder Flats areas. The Eckville storm moved eastward and dissipated near Clive about 1600. The Alder Flats storm moved eastward and out of the project area about 1900. Also, some activity near Stettler was present from 1600-1900.	–	–	–

APPENDIX 9. (continued)

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
August 5	–	No significant convection.	–	–	–
6	–	No significant convection.	–	–	–
7	–	No significant convection.	–	–	–
8	–	No significant convection.	–	–	–
9	1	Weak late afternoon and evening cells 70 - 90 mi. SW QF.	–	–	–
10	4	Storms developed around 2000 in a line from Olds to Camrose, with the most intense cells from Olds to Innisfail. The line dissipated between 2200 and 2300.	–	13	–
11	6	Two major storms left extensive hail in the project area. The first originated near Sundre near noon, and moved NE to exit the project area W of Stettler around 1900. The second originated W of RM in the early afternoon, moved ENE and dissipated NE of Stettler in the evening. A small weak storm was also present 30 mi. S QF between 2100 and 2200.	492	68	1.4 gal
12	2	Small, weak, eastward moving cells formed 50 mi. SSW QF at about 1400. Other small, isolated cells southeast and northeast QF later in the afternoon.	–	–	–
13	2	Weak afternoon and early evening cells formed SW and N of RM.	–	–	–
14	1	Frequent rainshowers, weak cells 80 mi. SW QF in the late afternoon.	–	–	–
15	1	Moderate intense cells developed near RM around 1400 and moved eastward through Lacombe to Forestburg by evening.	–	–	–
16	1	Weak storms E of Calgary at 1900 moved NE and dissipated near Drumheller by 2100. Weak overnight storm near Byemoore.	95	–	–
17	–	Weak cells developed near Drayton Valley in the late evening.	–	–	–
18	–	Weak early morning (0600) storm near Torrington.	–	–	–
19	–	No convection.	–	–	–
20	–	Late afternoon and evening rainshowers.	–	–	–
21	3	Small, weak, short-lived cells formed near the foothills and just N of YC in the afternoon. Between 1630 and 1700 several cells developed 50 - 100 mi. NW QF. These cells became a line of strong storms which moved through Penhold from the northwest at about 1930, and dissipated soon after S of Penhold.	146	23	–
22	1	A few evening showers occurred over the foothills with weak embedded convective cells.	–	–	–

APPENDIX 9. (continued)

DATE 1982	MISSIONS[1]	STORM SUMMARY[2]	TOP FLARES	BASE FLARES	ACETONE
August 23	6	Numerous weak cells were present W and S of Penhold throughout the afternoon, with similar cells E of Penhold in the mid-afternoon. More intense cells formed 30 - 40 mi. NW QF around 1630 but were short-lived. A line of cells of moderate intensity from 60 mi. NW QF to 55 mi. N QF to 35 mi. NE QF formed near 1700. The western portion of this line died about 1830 just NW of Sylvan Lake, while the eastern portion persisted until about 2000, where it finally weakened 20 mi. SE of Penhold.	–	52	1.8 gal
24	–	No significant convection.	–	–	–
25	–	Low overcast with light rain – no convection.	–	–	–
26	–	No significant convection.	–	–	–
27	1	A small, moderately intense storm formed 60 mi. WNW QF at about 1830, and moved eastward to near Eckville by 2000. Small convective cells also formed around 2000 to the SW of QF. All cells continued an eastward drift overnight.	–	–	–
28	2	No significant convection.	–	–	–
29	2	Weak afternoon and evening convective cells occurred 60 - 70 mi. SW QF.	–	–	–
30	2	Weak cells formed around 1400 70 mi. SW QF and moved SE, reaching moderate intensity and moving out of the project area near Cochrane at about 1700. Other weak, small cells persisted 60 mi. SW QF between 1830 and 2100.	–	8	–
31	–	Weak afternoon convective cells occurred north of RM and near Ponoka.	–	–	–

1. Seeding and patrol flights only
2. A subjective estimate of overall storm characteristics

ED - Edmonton
RD - Red Deer
RM - Rocky Mountain House
QF - Red Deer airport
YC - Calgary

APPENDIX 10. Monthly summary of hail days and hail reports from 1975 - 1982

NORTHERN AREA

Years	June	July	August	September	Total
		No. Hail Days/Month			
1982	7	16	13	2	38
1981	19	14	9	2	44
1980	18	21	17	2	58
1979	17	18	8	7	50
1978	20	18	8	2	48
1977	13	17	14	3	47
1976	11	16	12	2	41
1975	16	13	15	5	49
1974	12	16	13	2	43
Avg. 1974-82	15	17	12	3	46
Avg. 1957-82	13	15	10	2	39
		No. Hail Reports/Month			
1982	209	630	744	14	1597
1981	423	267	77	2	769
1980	93	939	492	2	1526
1979	315	993	211	157	1676
1978	537	820	227	12	1596
1977	207	426	257	192	1082
1976	307	733	526	8	1574
1975	207	1165	721	57	2150
1974	269	1153	298	7	1727
Avg. 1974-82	285	792	395	50	1522
Avg. 1957-82	333	742	334	24	1433

SOUTHERN AREA

Years	June	July	August	September	Total
		No. Hail Days/Month			
1982	12	15	12	1	40
1981	20	13	13	2	48
1980	16	18	19	3	56
1979	14	22	11	7	54
1978	13	16	7	5	41
1977	11	18	11	3	43
1976	8	13	10	1	32
1975	19	18	14	5	56
1974	10	10	12	1	33
Avg. 1974-82	14	16	12	3	45
Avg. 1957-82	12	15	9	2	38
		No. Hail Reports/Month			
1982	71	259	500	4	834
1981	329	469	258	2	1058
1980	317	1013	151	92	1573
1979	84	633	162	290	1169
1978	458	425	55	15	953
1977	162	474	132	199	967
1976	76	295	329	36	736
1975	357	394	319	9	1079
1974	328	422	523	5	1278
Avg. 1974-82	242	487	270	72	1072
Avg. 1957-82	286	608	297	35	1226

APPENDIX 10. (continued)

OUTSIDE PROJECT AREA

No. Hail Days/Month

Years	June	July	August	September	Total
1982	19	21	12	3	55
1981	21	18	14	2	55
1980	27	22	23	4	76
1979	21	20	15	6	62
1978	16	24	16	8	64
1977	22	25	18	4	69
1976	16	19	15	4	54
1975	25	17	18	7	67
1974	16	25	18	3	62
Avg. 1974-82	20	21	17	5	63

No. Hail Reports/Month

1982	56	160	52	4	272
1981	177	97	77	2	353
1980	200	153	116	14	483
1979	172	169	100	31	472
1978	379	177	96	53	705
1977	143	207	153	81	584
1976	193	174	203	8	578
1975	244	332	262	28	866
1974	178	559	75	8	820
Avg. 1974-82	194	225	126	25	570

COMBINED NORTHERN AND SOUTHERN AREAS

No. Hail Days/Month

Years	June	July	August	September	Total
1982	12	19	16	2	49
1981	23	16	15	3	57
1980	20	23	23	3	69
1979	18	24	14	7	63
1978	20	23	10	5	58
1977	18	22	16	3	59
1976	12	18	15	3	48
1975	23	20	18	6	67
1974	12	17	15	2	46
Avg. 1974-82	18	20	16	4	57
Avg. 1957-82	15	18	12	2	47

No. Hail Reports/Month

1982	280	889	1244	18	2431
1981	752	736	335	4	1827
1980	410	1952	641	94	3099
1979	399	1626	373	447	2845
1978	995	1245	282	27	2549
1977	369	900	389	391	2049
1976	383	1028	855	44	2310
1975	564	1559	1040	66	3229
1974	597	1575	821	12	3005
Avg. 1974-82	528	1279	664	123	2278
Avg. 1957-82	619	1350	631	59	2550

APPENDIX 10. (continued)

Daily log of maximum hail size reported from the southern area (Twp 26 - 36)

Date 1982	Shot	Pea	Grape	Walnut	Golfball	> Golfball	Unkown	No Hail	Total Hail
June 4	—	—	1	—	—	—	—	—	1
14	—	—	2	1	—	—	—	—	3
15	—	2	—	—	—	—	—	—	2
16	—	1	—	—	—	—	—	—	1
20	—	1	—	—	—	—	—	34	1
21	1	3	—	—	—	—	—	50	4
26	—	—	—	—	—	—	—	6	—
30	11	65	80	34	6	—	1	324	197
July 5	3	3	—	—	—	—	—	41	6
6	—	3	—	—	—	—	—	47	3
7	—	—	—	—	—	—	—	2	—
8	—	1	—	—	—	—	—	8	1
9	—	3	2	—	—	—	—	42	5
10	—	—	—	—	—	—	—	18	—
11	5	10	8	1	1	—	—	102	25
12	1	—	1	—	—	—	—	51	2
14	15	15	5	—	—	—	—	129	35
17	3	1	—	—	—	—	—	70	4
18	1	1	1	—	—	—	—	118	3
21	21	73	104	88	65	43	1	254	395
22	—	—	2	—	—	—	2	6	4
23	11	35	3	—	1	—	—	146	50
24	—	—	1	—	—	—	—	—	1
25	1	23	8	—	—	—	—	167	32
29	3	4	11	5	3	1	—	100	27
31	3	16	16	1	1	—	—	232	37
Aug. 1	16	43	54	11	1	—	—	278	125
2	3	1	—	—	—	—	2	39	6
3	1	5	1	—	—	—	—	56	7
4	7	36	8	—	—	—	—	157	51
10	—	—	—	—	—	—	—	132	—
11	33	106	82	53	23	3	—	229	300
12	7	7	—	—	—	—	1	121	15
13	—	2	—	—	—	—	—	17	2
15	5	7	7	—	—	—	—	181	19
16	—	—	—	—	—	—	—	2	—
17	1	—	—	—	—	—	3	20	4
19	—	—	—	—	—	—	—	6	—
21	8	25	10	1	1	—	—	131	45
23	51	83	14	1	—	—	—	326	149
27	4	7	4	—	—	—	—	119	15
31	3	3	—	—	—	—	—	106	6
Sept. 3	2	8	—	—	—	—	—	11	10
10	1	2	1	—	—	—	—	—	4

APPENDIX 10. (continued)

Daily log of maximum hail size reported from the northern area (Twp 37 - 47)

Date 1982	Shot	Pea	Grape	Walnut	Golfball	> Golfball	Unknown	No Hail	Total Hail
June 4	—	—	1	—	—	—	—	—	1
9	1	2	—	—	—	—	—	—	3
11	—	2	—	—	—	—	—	—	2
14	—	1	—	—	—	—	—	—	1
15	1	2	1	—	—	—	—	—	4
16	—	2	—	—	—	—	—	—	2
19	—	1	—	—	—	—	—	—	1
20	1	1	4	—	—	—	—	37	6
21	6	16	9	1	—	1	—	80	33
22	—	1	—	—	—	—	—	12	1
23	—	—	—	—	—	—	—	6	—
24	—	—	—	—	—	—	—	2	—
26	2	3	—	--	—	—	—	149	5
30	2	4	5	—	—	1	—	52	12
July 6	1	5	1	—	—	—	—	88	7
8	1	—	—	—	—	—	—	12	1
9	—	10	2	1	—	—	—	113	13
10	—	—	1	—	—	—	—	43	1
12	7	10	4	1	—	—	1	190	23
13	1	—	—	—	—	—	—	9	1
14	4	9	—	—	—	—	—	53	13
17	—	—	—	—	—	—	—	42	—
18	—	6	3	1	—	—	—	33	10
21	2	6	13	2	—	—	1	46	24
22	2	—	—	—	—	—	—	7	2
24	3	6	3	1	1	—	—	71	14
25	10	21	9	3	—	—	—	233	43
27	1	4	—	—	—	—	—	27	5
29	1	6	4	3	1	—	—	44	15
31	12	41	29	5	—	—	—	348	87
August 1	1	2	7	1	—	—	—	43	11
2	30	76	41	14	3	—	1	248	165
3	19	36	34	9	1	—	1	250	100
10	5	1	—	—	—	—	—	102	6
11	8	30	51	31	5	1	1	108	127
12	7	2	—	—	—	—	—	90	9
16	—	—	—	—	—	—	—	5	—
17	3	4	—	—	—	—	1	27	8
18	—	2	—	—	—	—	1	29	3
21	—	3	—	—	—	—	—	19	3
23	3	4	—	—	—	—	—	69	7
27	4	8	1	—	—	—	2	95	15
30	12	27	6	—	—	—	1	51	46
31	—	—	—	—	—	—	—	21	—
Sept. 10	—	2	2	—	—	—	—	—	4

APPENDIX 10. (continued)

Daily log of maximum hail size reported from outside the project area

Date 1982	Shot	Pea	Grape	Walnut	Golfball	> Golfball	Unknown	No Hail	Total Hail
June 4	1	1	—	—	—	—	—	—	2
5	1	—	—	—	—	—	—	—	1
6	—	1	—	—	—	—	—	—	1
8	—	1	—	—	—	—	—	—	1
9	—	2	1	—	—	—	—	—	3
10	—	3	—	—	—	—	—	—	3
13	—	1	—	—	—	—	—	—	1
14	—	3	1	—	—	—	—	—	4
15	—	4	2	—	—	—	—	—	6
16	—	3	—	—	—	—	—	—	3
19	—	1	1	—	—	—	—	—	2
21	—	1	—	—	—	—	—	—	1
23	—	1	—	—	—	—	—	—	1
24	—	—	1	—	—	—	—	—	1
25	—	—	1	—	—	—	—	—	1
26	—	2	—	—	—	—	—	—	2
27	1	1	5	1	—	—	—	—	8
30	—	2	2	6	3	2	—	4	15
July 1	—	1	4	—	—	—	—	—	5
4	1	—	—	—	—	—	—	—	1
5	4	—	—	—	—	—	—	—	4
6	1	3	—	—	—	—	—	—	4
7	—	3	—	—	—	—	—	—	3
9	—	1	2	—	—	—	—	10	3
10	—	—	—	1	—	—	—	—	1
11	1	7	20	7	3	—	—	45	38
12	—	—	—	—	—	—	—	4	—
13	—	3	1	—	—	—	—	—	4
15	—	2	—	—	—	—	1	—	3
16	—	2	—	—	—	—	—	—	2
18	—	—	3	1	—	—	—	5	4
19	—	1	—	—	—	—	1	—	2
21	—	7	12	10	11	4	1	4	45
22	—	—	—	1	—	—	—	1	1
23	1	2	3	—	—	—	—	4	6
24	—	3	—	—	—	—	—	—	3
25	—	10	8	4	3	—	1	1	26
27	—	—	1	—	—	—	—	—	1
29	—	—	2	—	—	—	—	—	2
31	—	2	—	—	—	—	—	—	2
Aug. 1	—	—	—	—	—	—	—	3	—
3	—	—	—	—	—	—	—	1	—
4	—	1	3	1	—	—	—	3	5
10	—	3	6	1	2	—	—	—	12
11	—	—	4	2	2	—	—	—	8
12	—	3	—	—	—	—	—	—	3
13	—	3	—	—	—	—	—	—	3
14	—	1	3	—	—	—	—	—	4
15	—	1	—	—	—	—	—	3	1
18	—	1	—	—	—	—	—	—	1
20	—	4	—	—	—	—	—	—	4
21	—	1	—	—	—	—	—	—	1
23	1	3	4	—	—	—	—	2	8
30	—	2	—	—	—	—	—	—	2
Sept. 3	—	1	—	—	—	—	—	—	1
10	—	2	—	—	—	—	—	—	2
15	—	1	—	—	—	—	—	—	1

APPENDIX 10. (continued) Hail card format

Storm Date: _____ 1982

Day of Week: _____

Location ____ ¼ S ____ T ____ R ____

W of ____

Hail: Began _____ am _____ pm

Lasted for _____ minutes

Storm Approached From What Direction _____

Rain: Began _____ am _____ pm

Lasted for: _____ minutes

Measured _____ mm

Estimated _____ mm

Largest Hailsize:

Shot ☐ Pea ☐ Grape ☐

Walnut ☐ Golf Ball ☐ Larger ☐

Most Common Hailsize:

Shot ☐ Pea ☐ Grape ☐

Walnut ☐ Golf Ball ☐ Larger ☐

Average Spacing of Stones _____ mm

or Depth of Hail _____ mm

or Ground Just Covered ☐

Wind: Light ☐ Moderate ☐ Strong ☐ Severe ☐

Lightning: Yes ☐ No ☐ Don't know ☐

Crop: (type) _____

Estimated Damage _____ %

3-5 leaf ☐ Shot Blade ☐ Heading ☐

Blooming ☐ Dough ☐ Mature ☐

Remarks: _____

_____

_____

_____

Thanks for your help. If you would rather phone in your hail report just call collect 886-4431. If you are ever in the area please drop in for a visit. Looking forward to hearing from you.

Name _____

Address _____

Postal Code _____ Phone _____

L P C

APPENDIX 11. Daily meteorological and storm data summaries

Appendix 11 covers all days during the operational cloud seeding period with either:

a) 10 or more hail reports received,
b) grape-sized hail reported, or
c) cloud seeding activity.

Data for each day includes:

a) a 500 mb height and thickness analysis for 1800 MDT (2400Z),
b) a representative upper-air sounding (tephigram) with hodograph.
c) a hailfall and cloud seeding summary map.

The 500 mb maps are reproduced from official AES microfilm records. Solid isopleths on the analysis are height contours at 60 m intervals, and dashed isopleths are 1000 - 500 mb thickness at 60 m intervals.

Soundings for either CYYC, CAQF or CWEG were chosen with due respect to development areas, motion and timing of the most significant storm cells. These show dry bulb (solid line) and dew point (broken line) temperatures, and the moist adiabat that best represents the storms for that day. The short horizontal bar represents cloud base. Each moist adiabat was derived from values of maximum temperature and mixing ratio (labelled at the base of the sounding) judged to be the most representative for the storm area, and not necessarily at the radiosonde station itself. Mixing ratios (to the nearest 0.5 g kg^{-1}) were obtained by averaging over 50 mb or less in the mixing layer. Heights given are with reference to MSL.

Legend:

- general hailswath areas
- walnut and larger hail areas
- operational cloud seeding
- research cloud seeding
- △ CO_2 cloud seeding

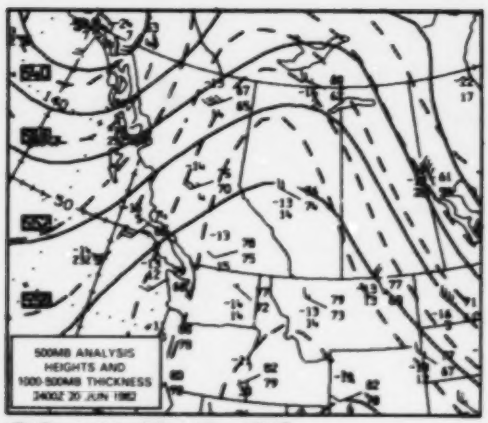
Storm dates include:

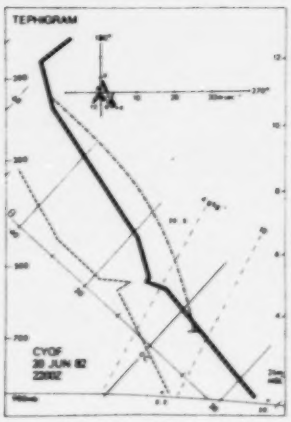
June: 20, 21, 26, 27, 30

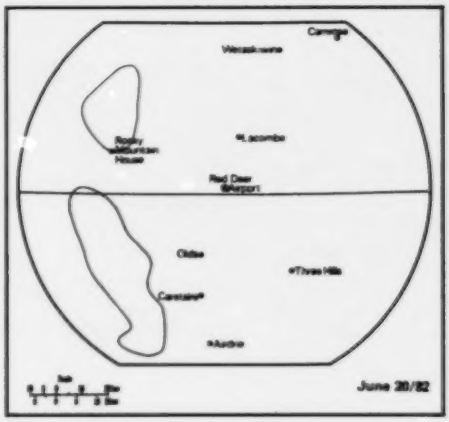
July: 3, 6, 7, 8, 9, 10, 11, 12, 14, 16, 17, 18, 21, 22, 23, 24, 25, 29, 31

August: 1, 2, 3, 4, 10, 11, 12, 15, 16, 17, 21, 23, 27, 30

APPENDIX 11. Daily meteorological and storm data summaries







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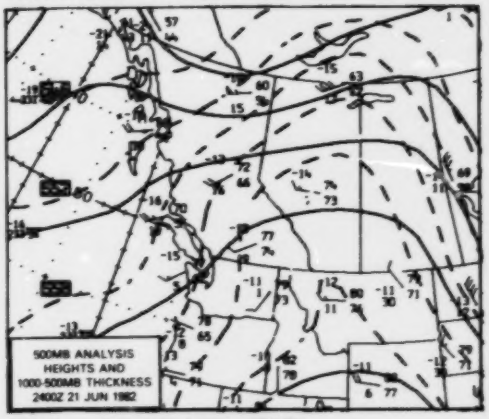
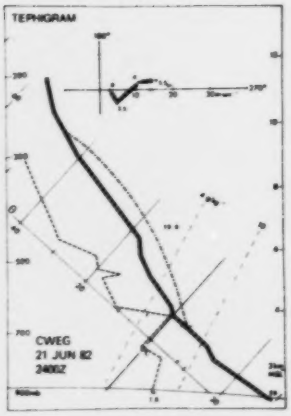
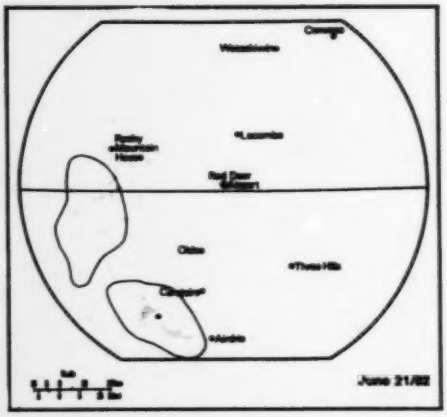
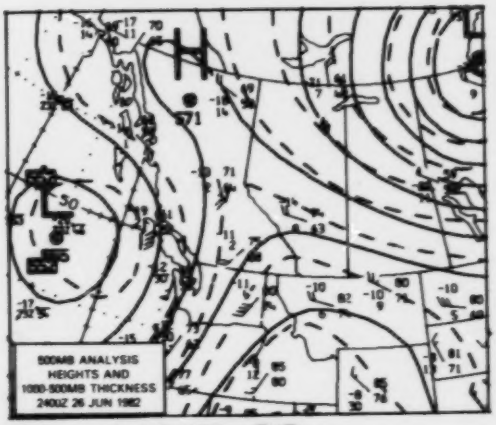
APPENDIX 11. (continued)

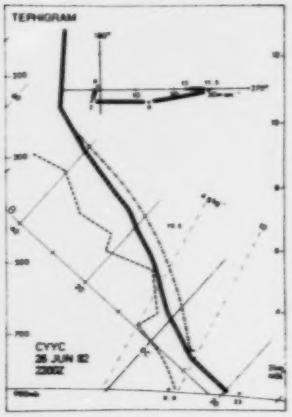


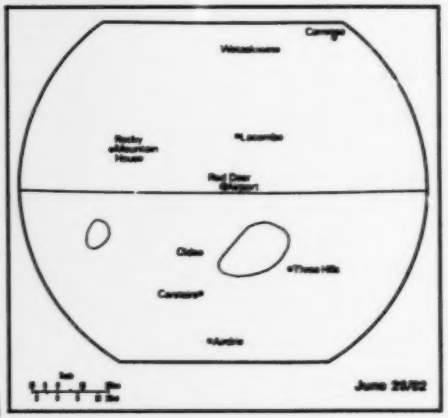




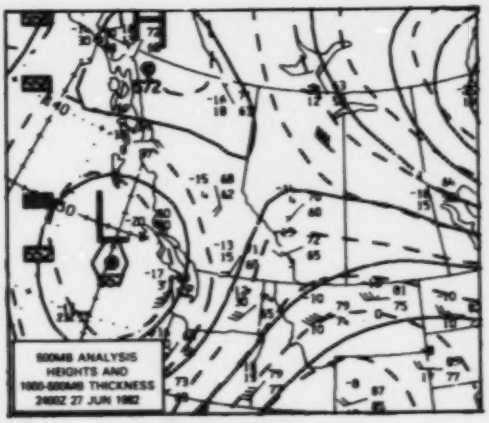
21 JUNE 82

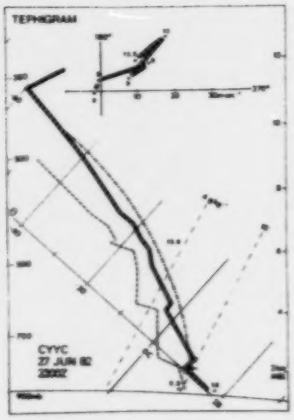


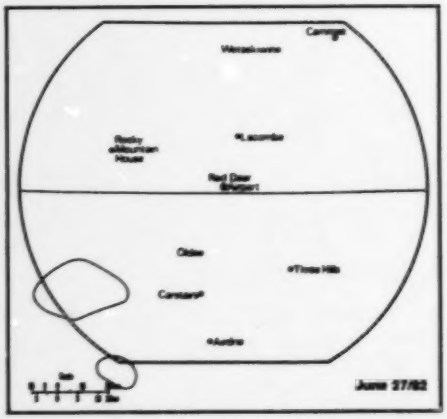




26 JUNE 82







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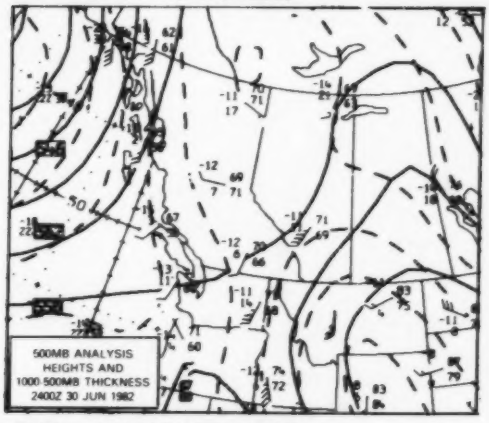
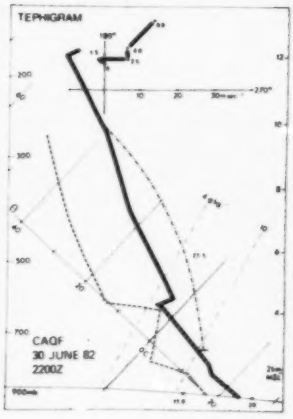
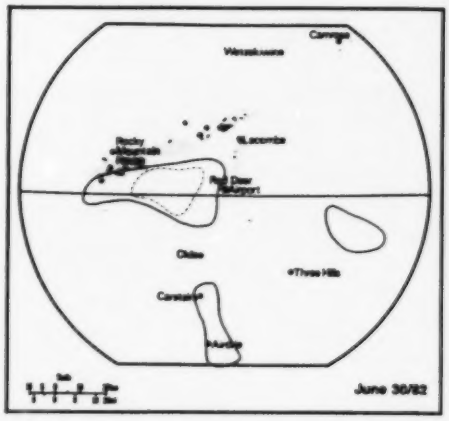
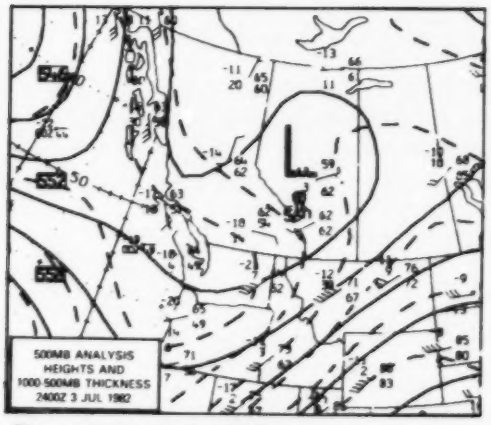
APPENDIX 11. (continued)

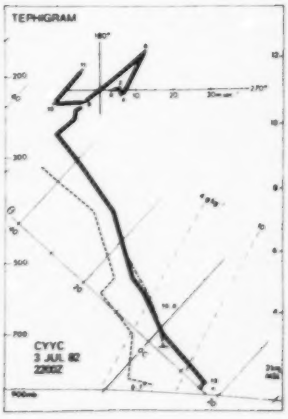


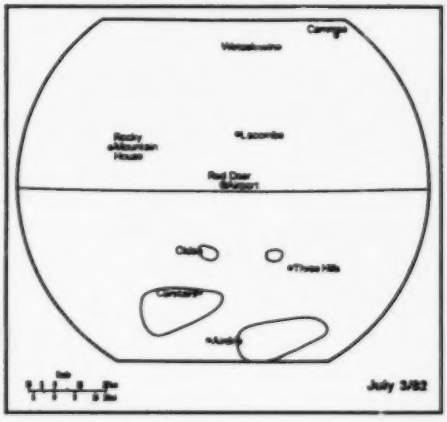




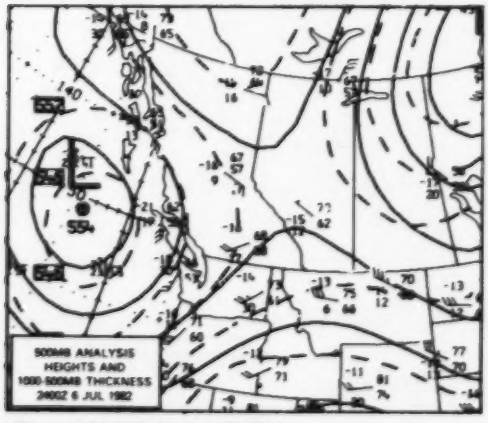
30 JUNE 82

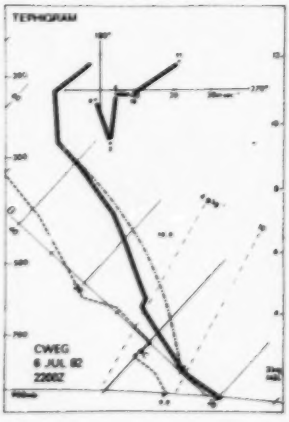


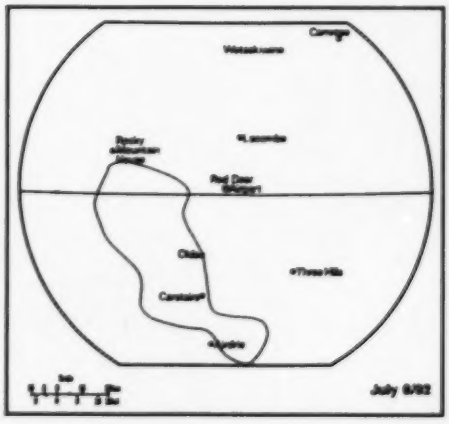




3 JULY 82

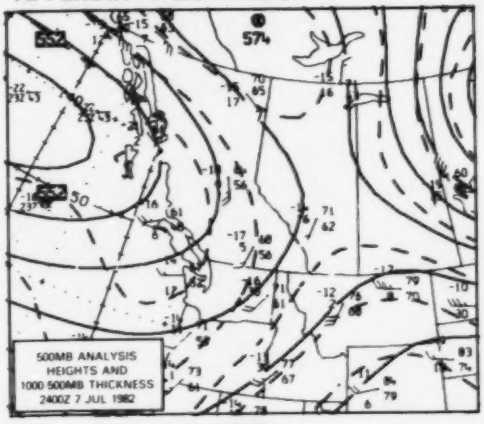


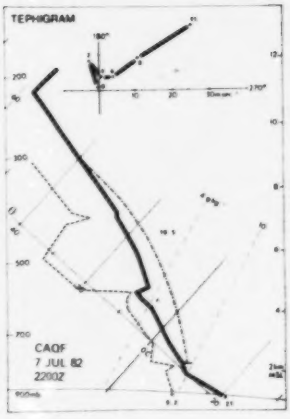


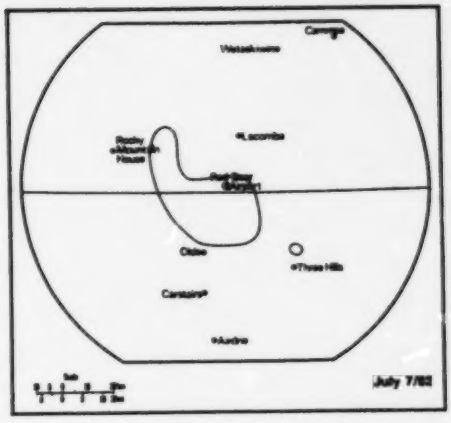


6 JULY 82

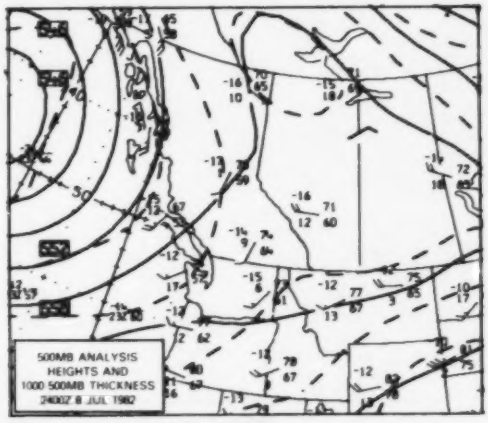
APPENDIX 11. (continued)

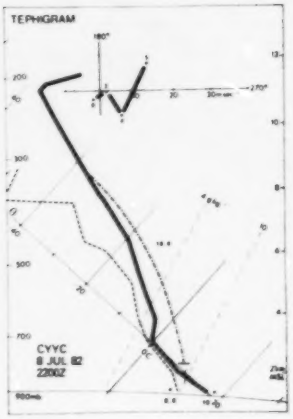


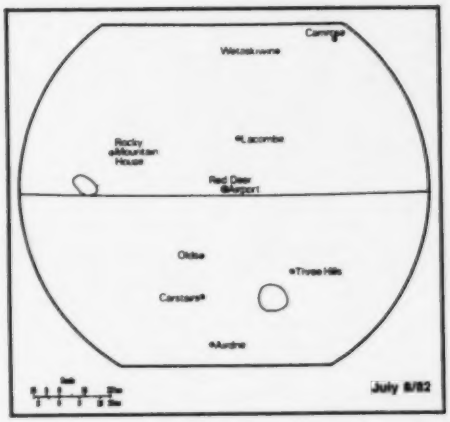




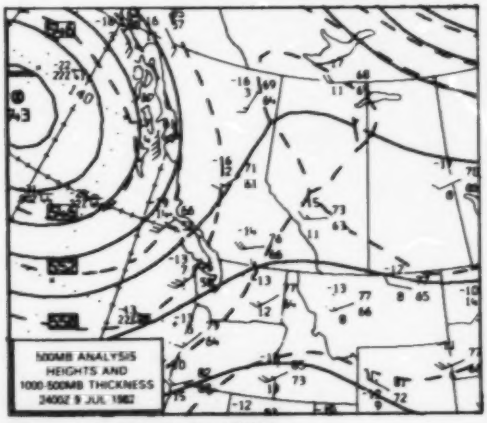
7 JULY 82

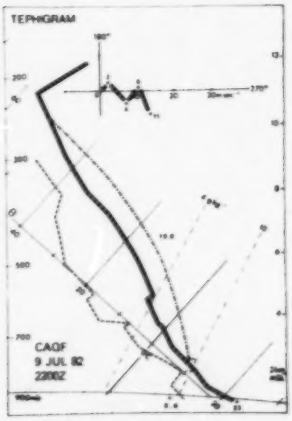


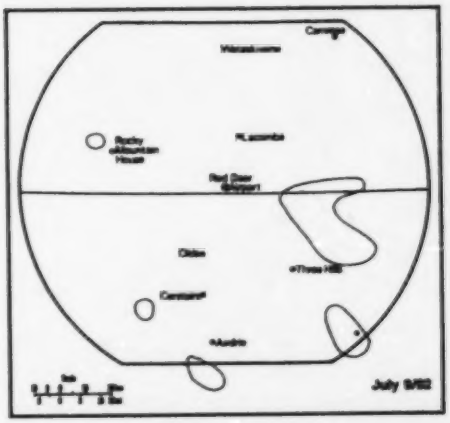




8 JULY 82

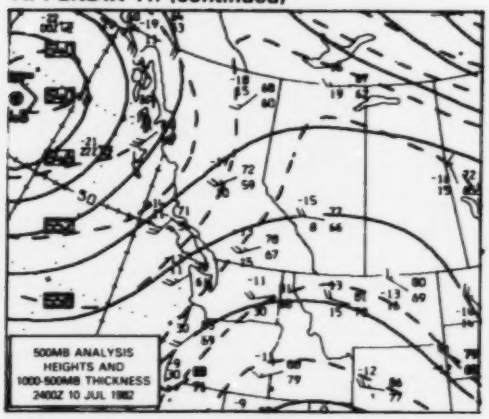


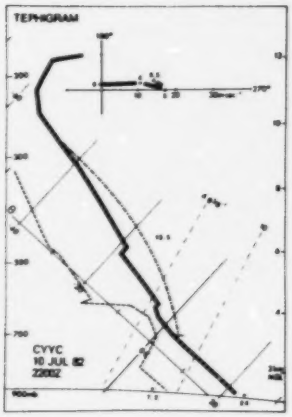


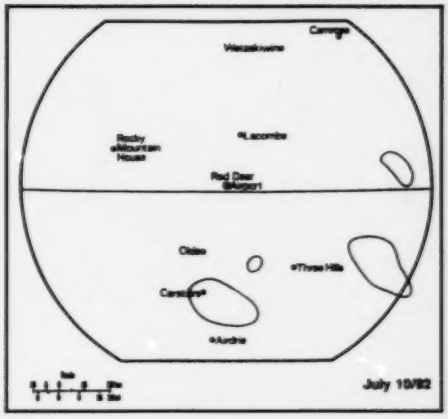


9 JULY 82

APPENDIX 11. (continued)







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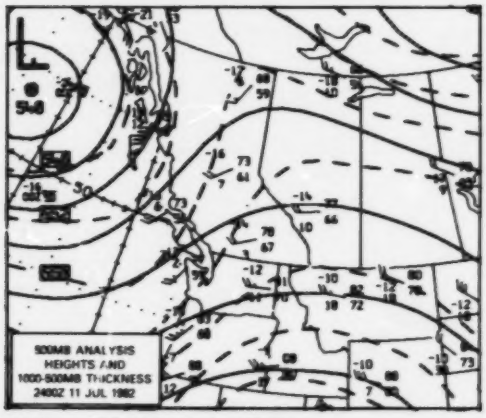
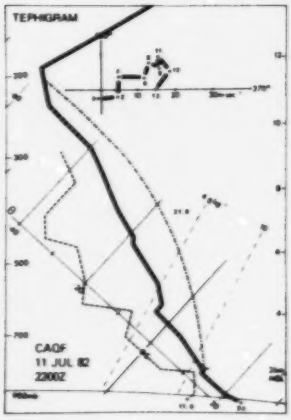
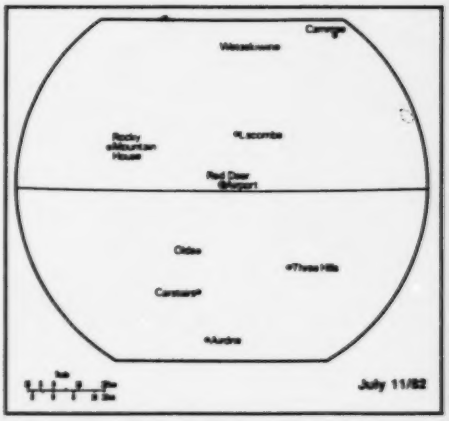
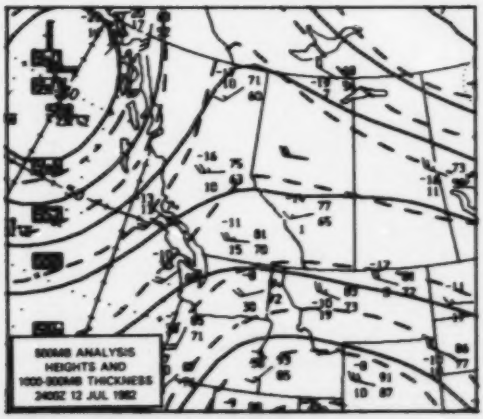
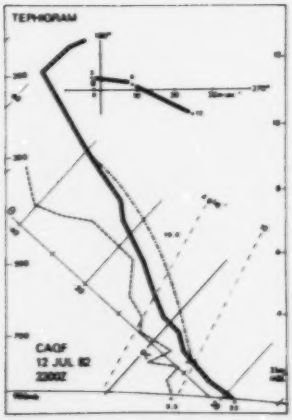


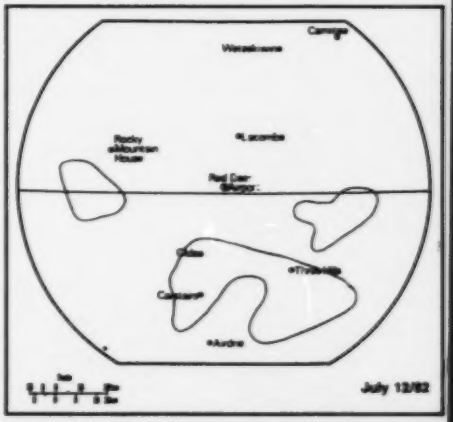




11 JULY 82

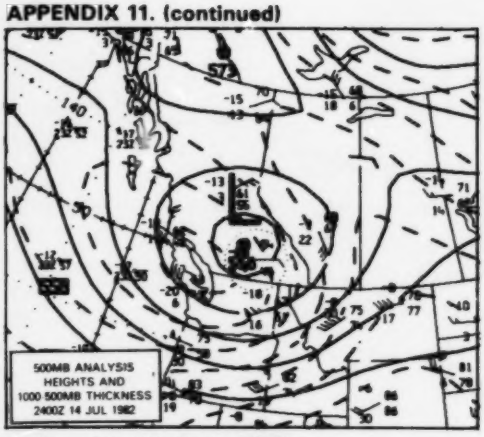


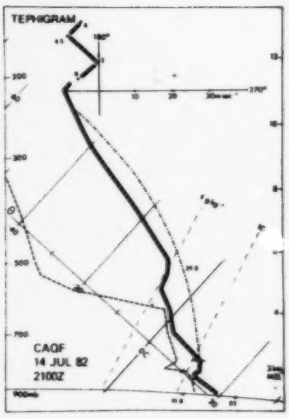


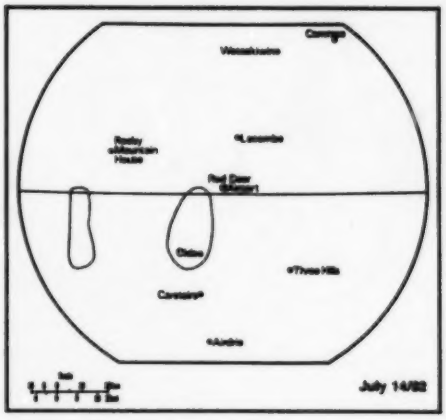


12 JULY 82

APPENDIX 11. (continued)







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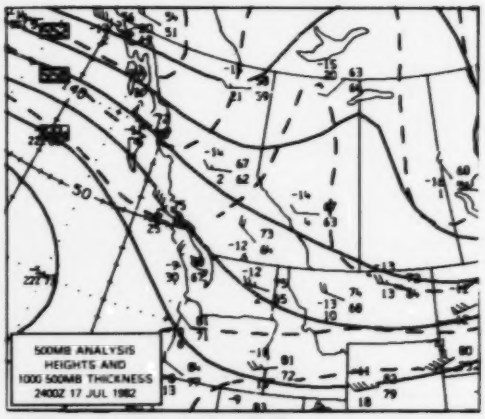
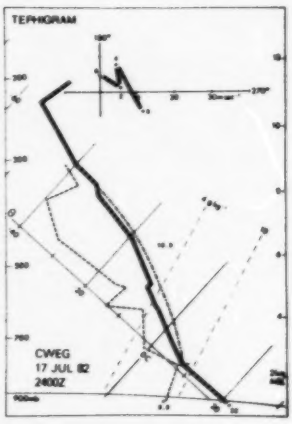
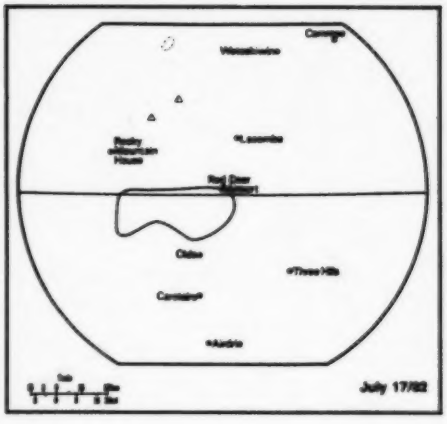
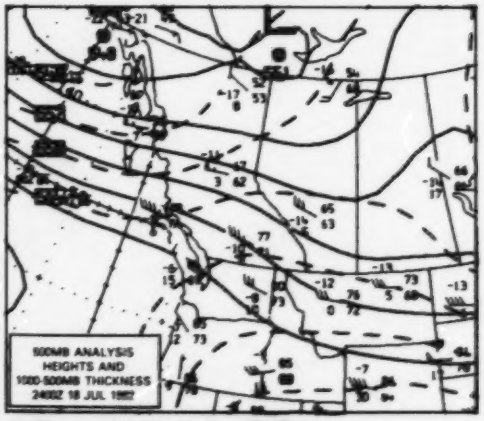
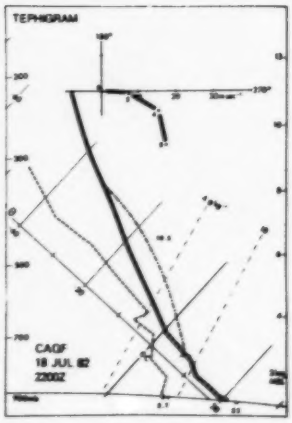


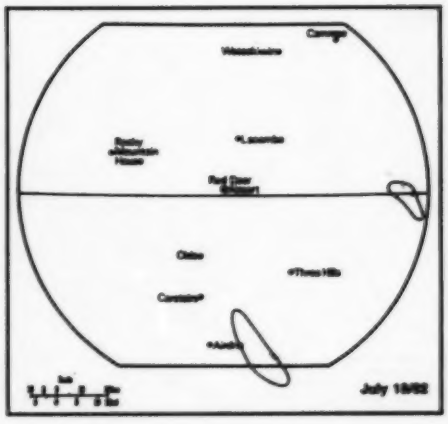




17 JULY 82

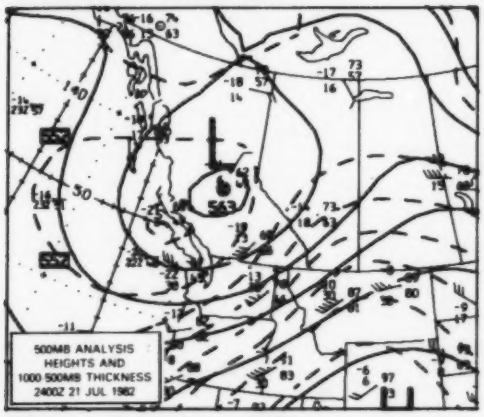


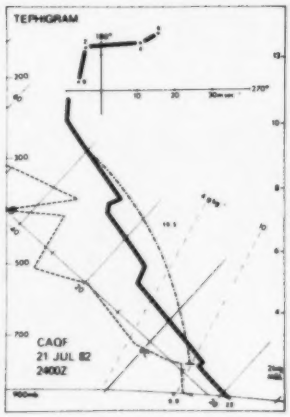


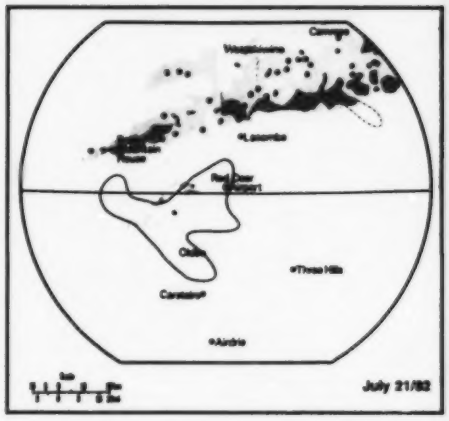


18 JULY 82

APPENDIX 11. (continued)







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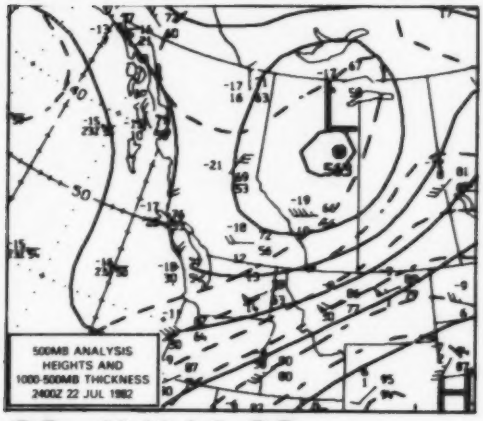
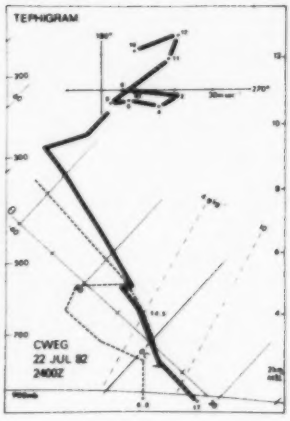
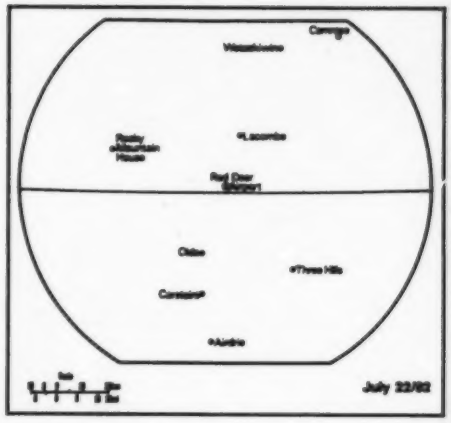
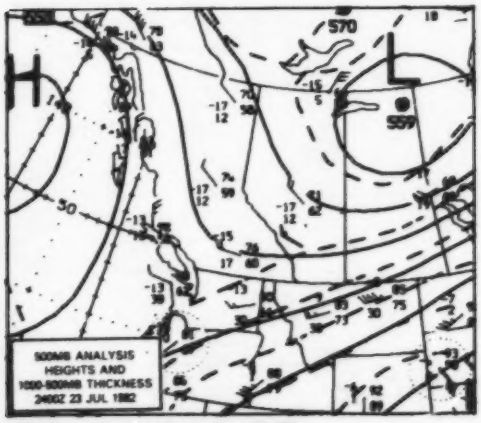
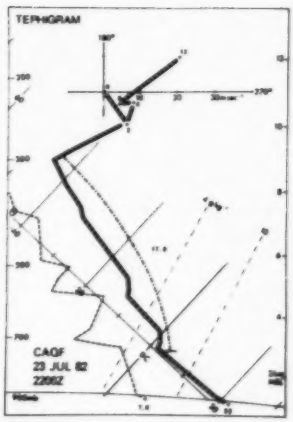


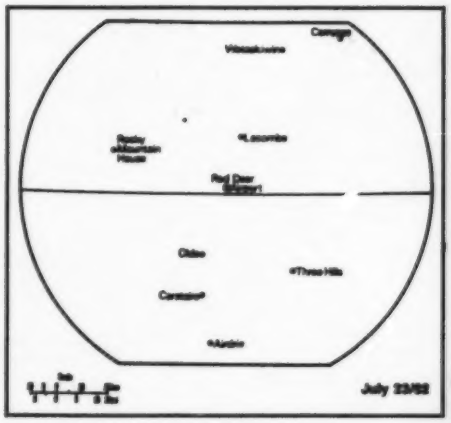




22 JULY 82

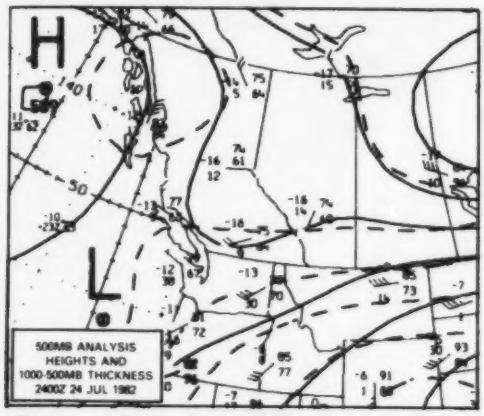


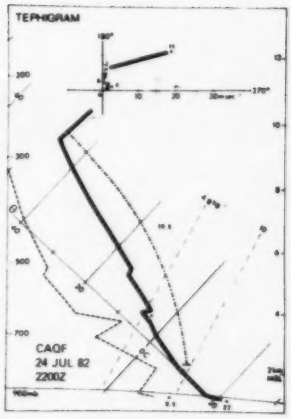


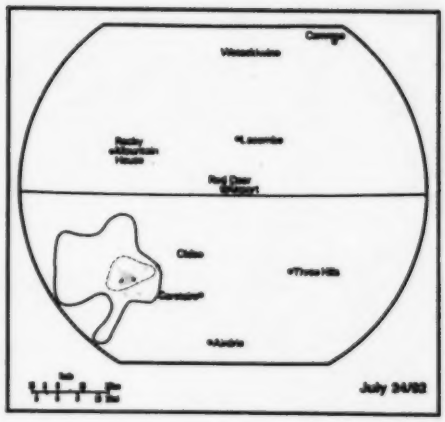


23 JULY 82

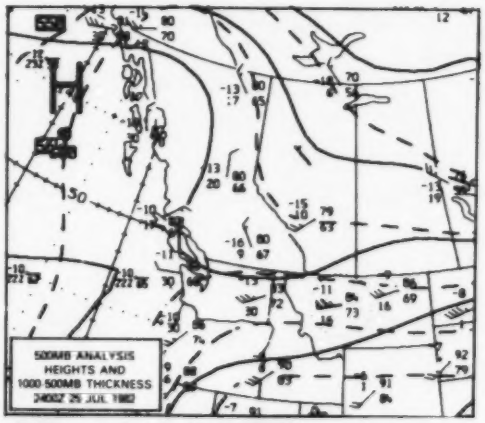
APPENDIX 11. (continued)

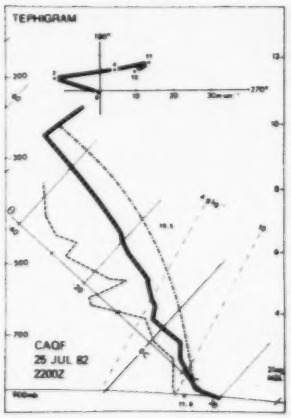


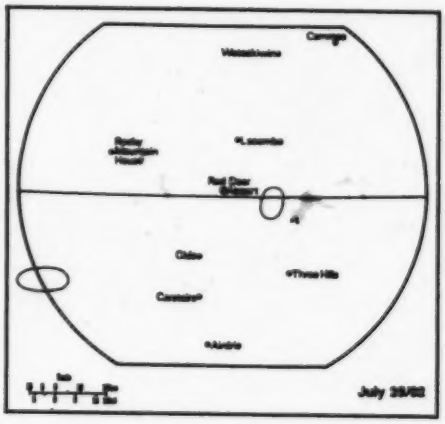




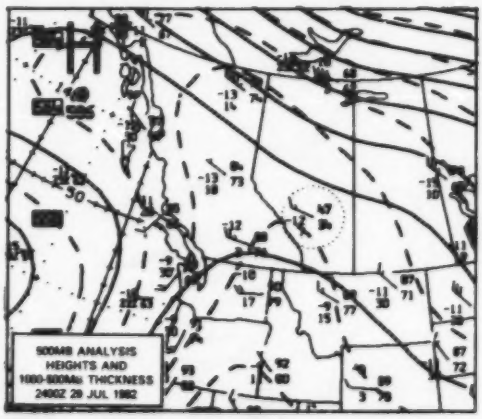
24 JULY 82

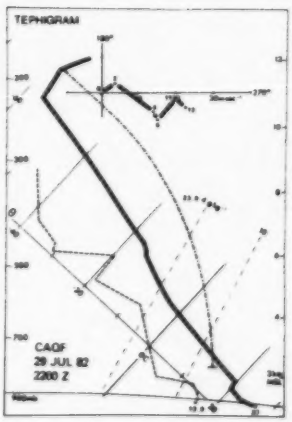


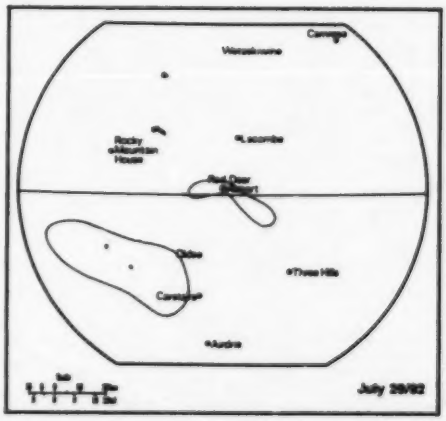




25 JULY 82







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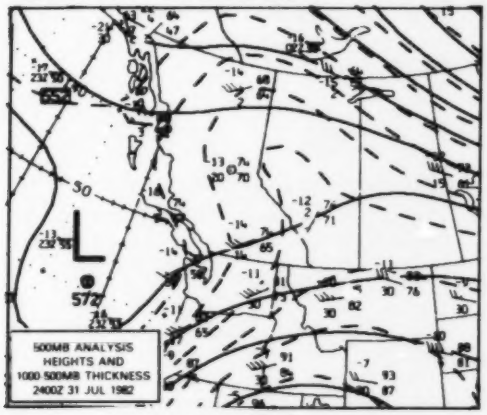
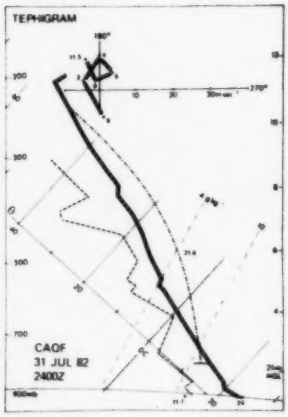
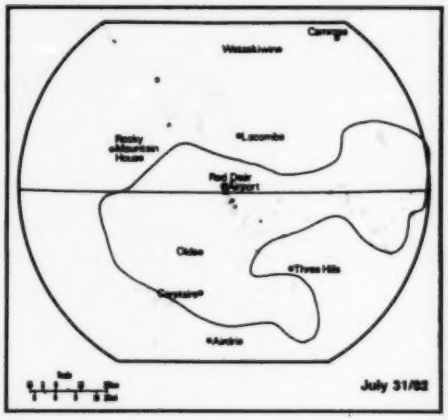
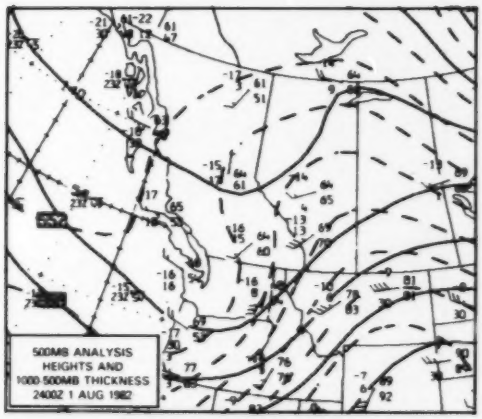
APPENDIX 11. (continued)

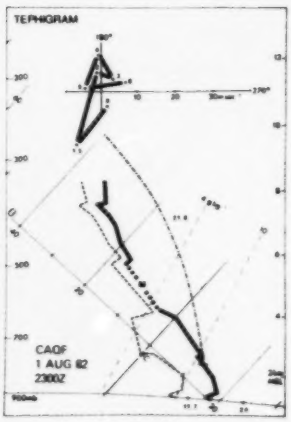


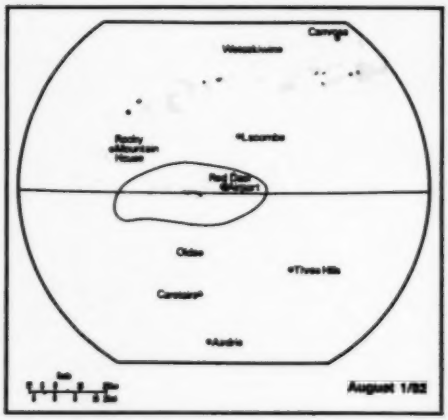




31 JULY 82







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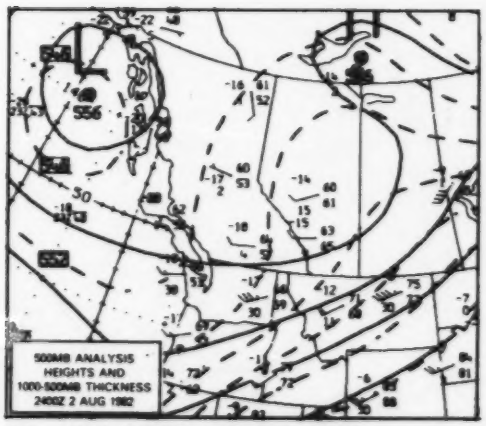

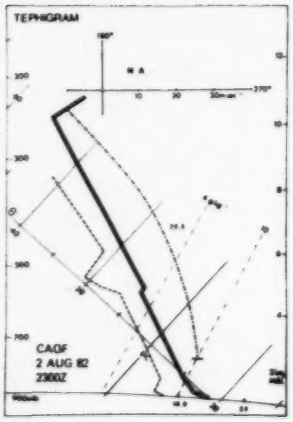

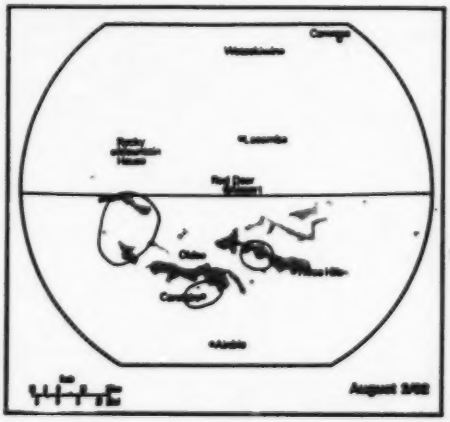

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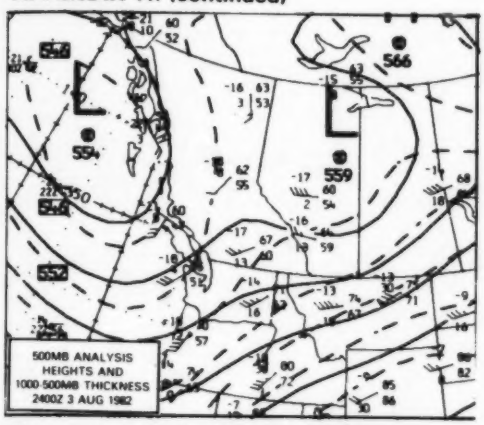
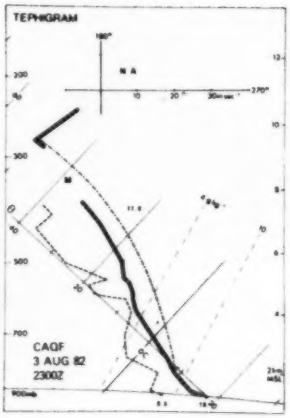
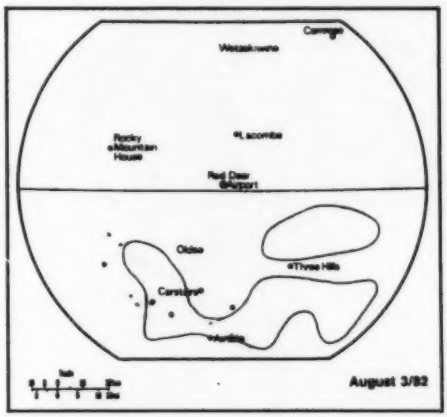
APPENDIX 11. (continued)







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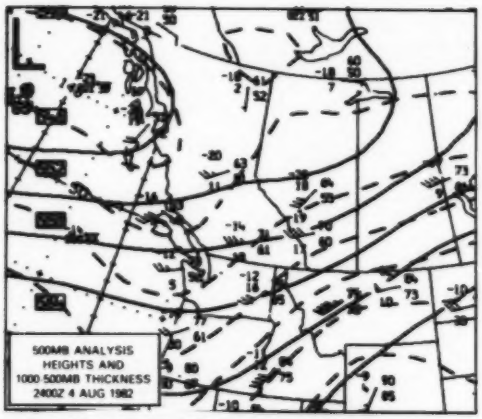

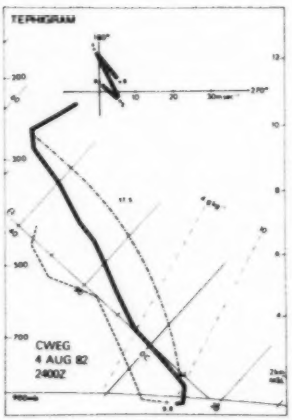

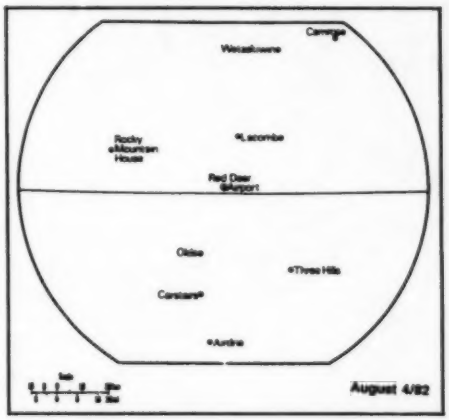

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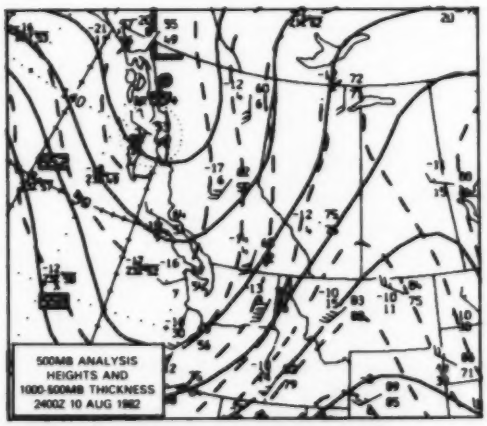

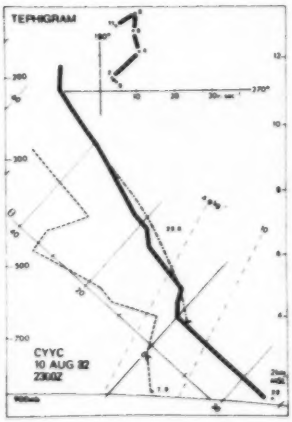

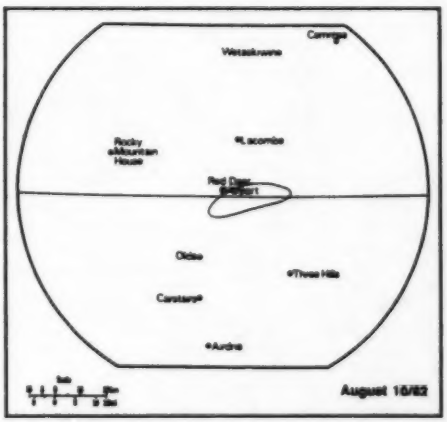

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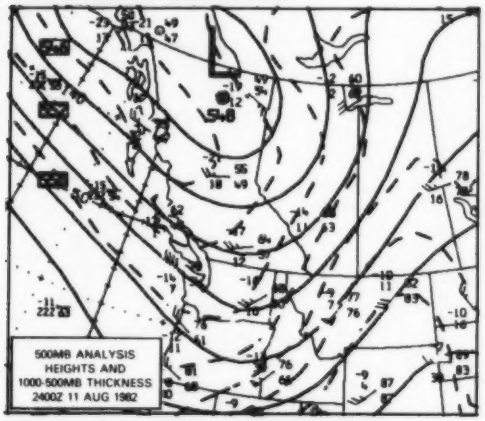
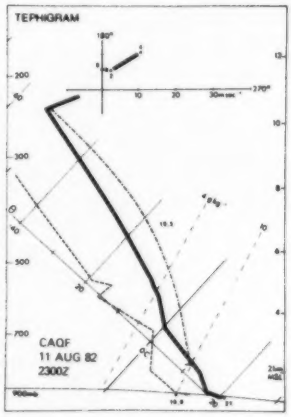
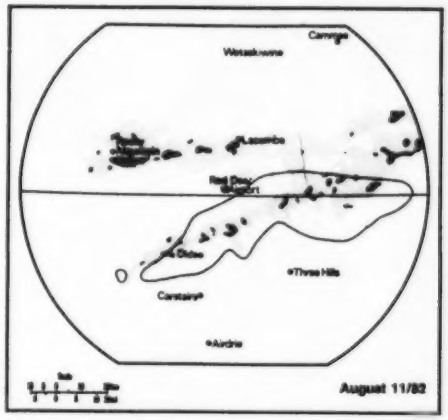
APPENDIX 11. (continued)







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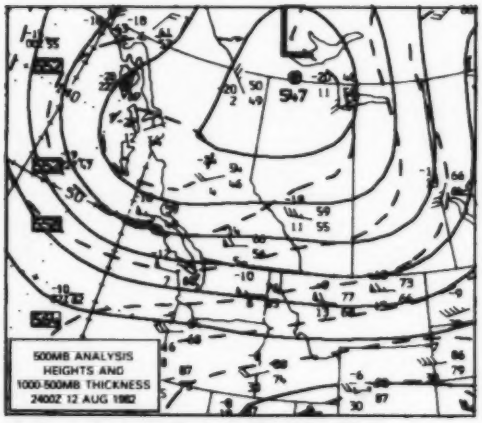

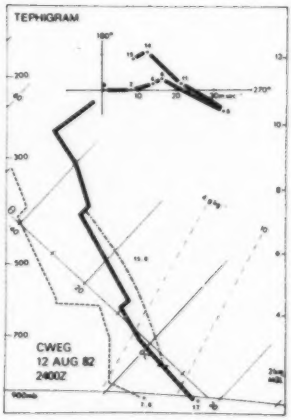

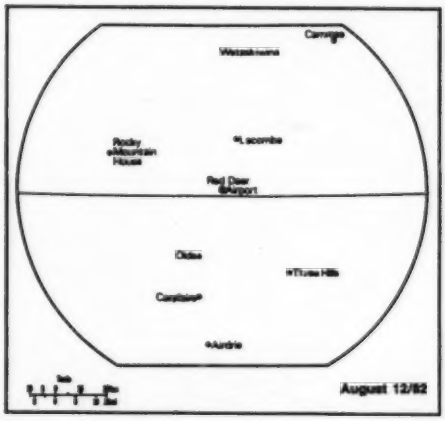

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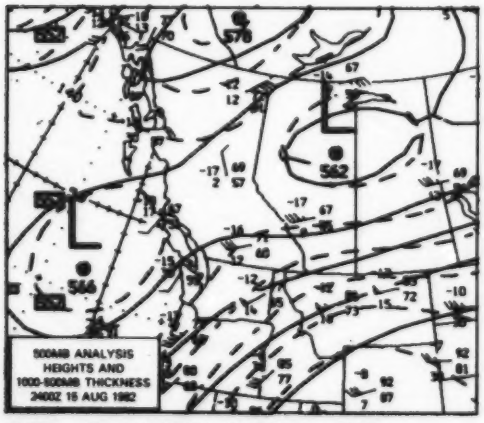

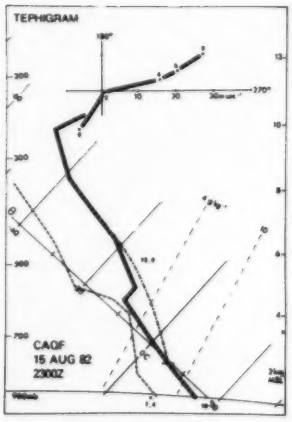

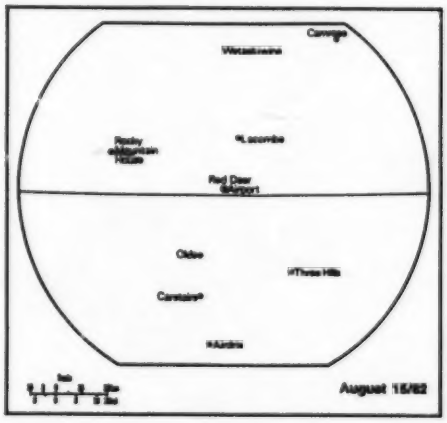

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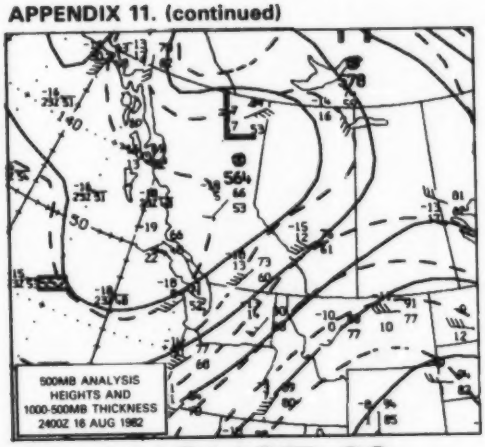
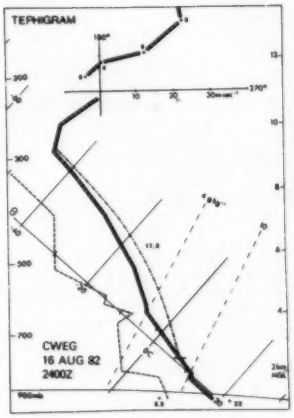
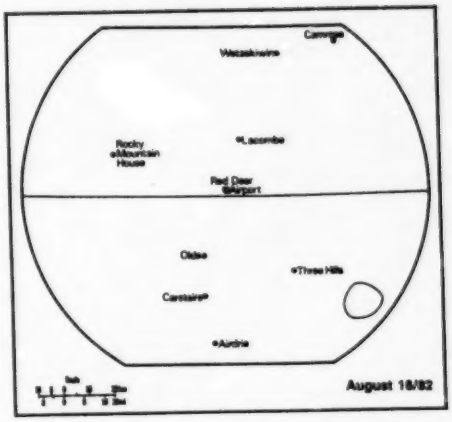
APPENDIX 11. (continued)







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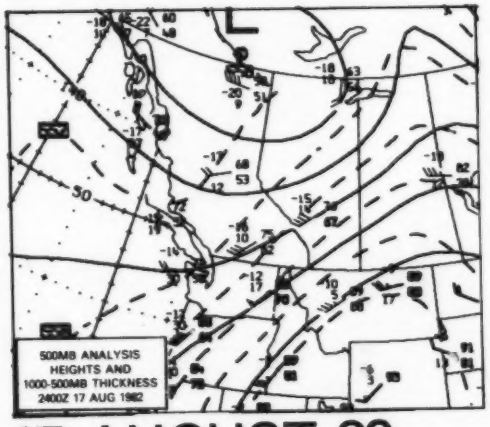

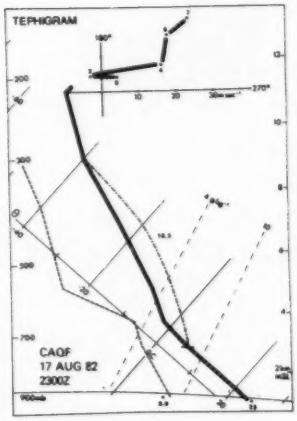

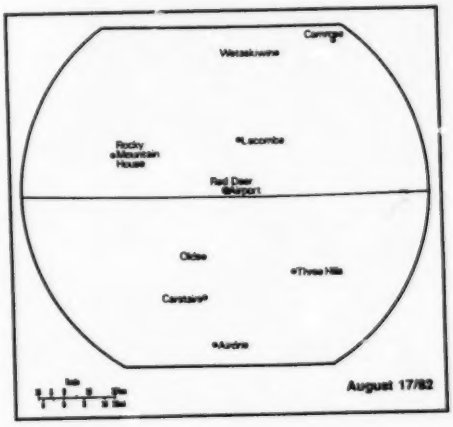

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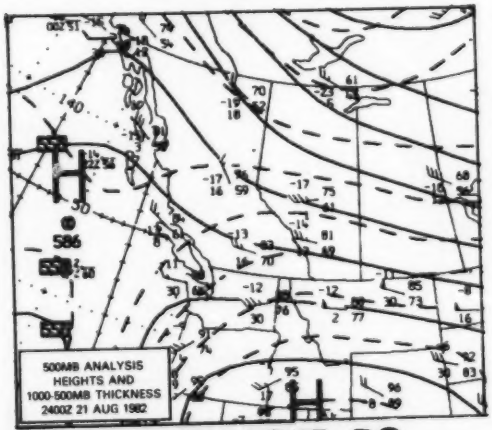

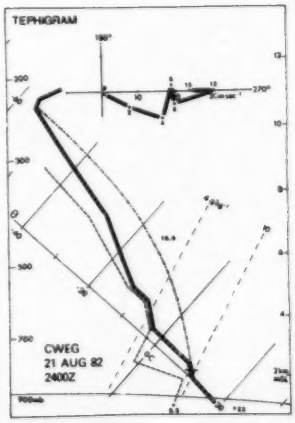

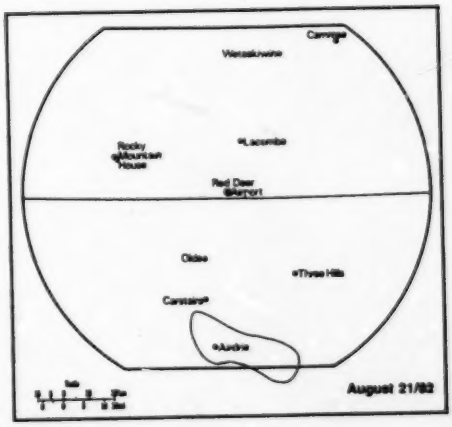

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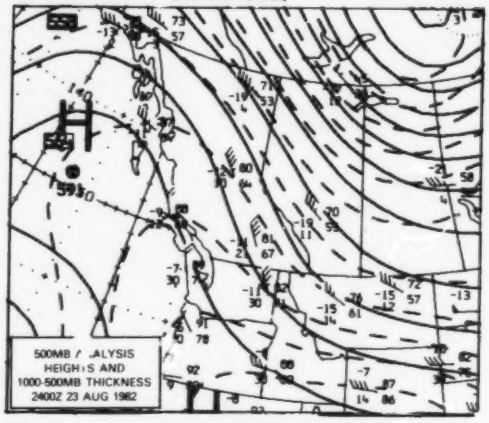
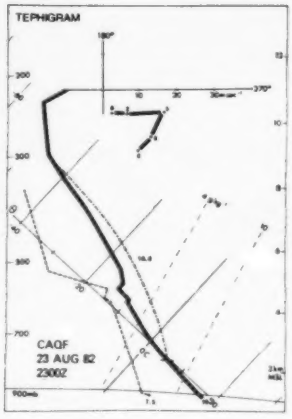
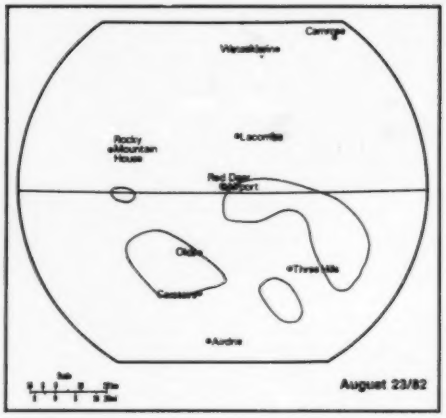
APPENDIX 11. (continued)







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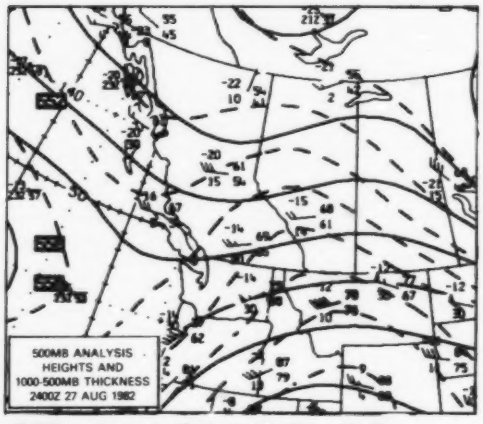

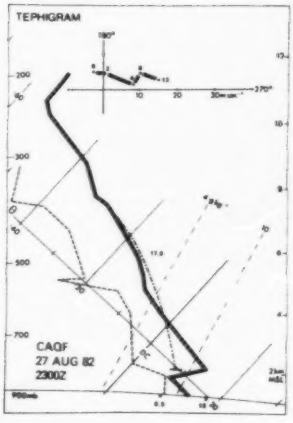

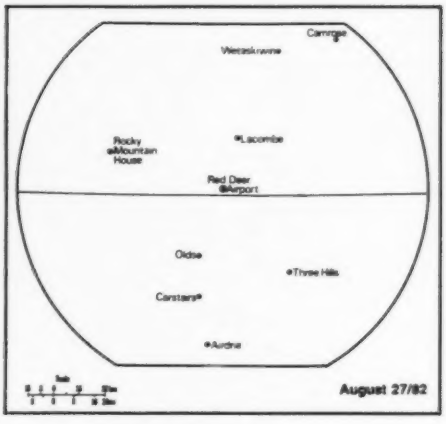

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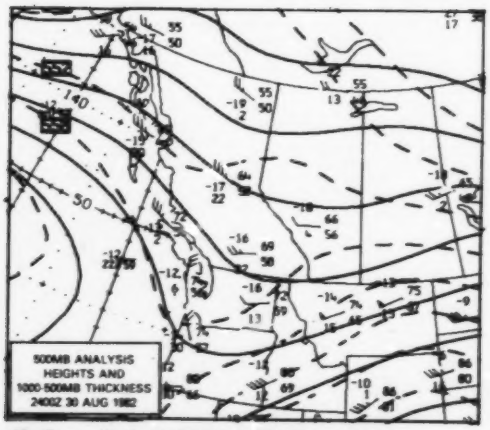

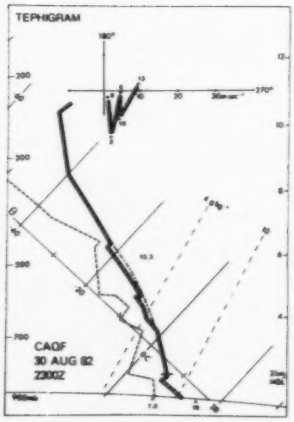

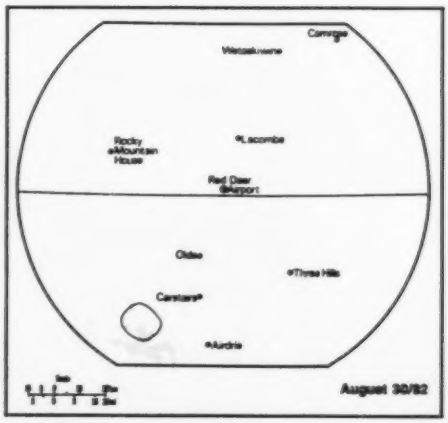

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